

**ROBOTICS
AND STEM
EDUCATION FOR
CHILDREN AND
PRIMARY SCHOOLS**

www.botstem.eu

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Dear teacher,

We are very pleased to introduce the **botSTEM** Toolkit, created to provide **digital support** for integrated Science, Technology, Engineering and Mathematics (**STEM**) in **early-years education** in a more **motivating and appealing way**. Freely available and downloadable, the **botSTEM** Toolkit implements **innovative methodologies** using inquiring teaching and computational thinking and **develops tools, resources and methods** specifically for teachers. The **botSTEM** aims to support development of **integrative STEM education** by introducing **robotics and code-learning**, so that children are given the opportunity to practice skills such as **logical thinking, problem solving, digital competence, reasoning, reflection, questioning, modelling, justifying decisions and communication**.

THE STRUCTURE...

- A. A **theoretical framework** for an integrated and inclusive STEM approach, on a pedagogical basis and with methodologies for introducing STEM and computational thinking to young students.
- B. A selection of **good practices in STEM education and robotics**, produced and tested by teachers of different European countries.
- C. A group of **new activities**, designed within the theoretical framework proposed, for developing STEM concepts, ideas and competences, making stepwise use of robotics, code learning, and physical computation.
- D. A selection of **Open Educational Resources**, useful for teachers wishing to introduce STEM approaches, collaborative inquiry teaching, code learning and programming for 4-8 year old pupils.

A LITTLE BIT ABOUT OUR PROJECT...

botSTEM is an **ERASMUS+ KA201** project with partners in Spain (coordinators), Sweden, Italy and Cyprus. It is focused on the contents of this Toolkit. With this Toolkit, we are developing a Virtual Learning Environment, to aid teachers in the introduction of innovative approaches in their classrooms. More information can be found at www.botstem.eu.



Sincerely,

01

THEORETICAL FRAMEWORK

Pedagogical framework - integrated, gender-inclusive STEM through inquiry-based teaching for early childhood education

WHY INTEGRATED STEM EDUCATION?

Over past decades, many science educators have stated that solid scientific literacy is essential for life in modern society. Furthermore, there is a concern in the Western world over the reduced numbers of young people who are deciding to follow studies in science and technology.

In response, policymakers are now actively promoting measures to develop positive attitudes towards Science, Technology, Engineering and Mathematics that will help citizens to acquire the scientific knowledge and competences that are needed for them to engage in society in an active and responsible manner (EC, 2015).

More specifically, the 'Horizon 2020' initiative proposed by the European Commission has stressed the need to make science education attractive for all young people (EC, 2016), and to promote approaches to reduce "leakages" in the science pipeline.

Taking into account the failure of traditional science teaching, mainly reductionist in its treatment of science, mathematics, and technology as separate disciplines, a new approach, known as STEM (Science, Technology, Engineering & Mathematics), has proposed the introduction of those disciplines, in an integrated modality, from an early age (Honey, Pearson, & Schweingruber, 2014).

The idea of STEM education is the conceptualization of these disciplines as a cohesive entity, the teaching of which is integrated and coordinated as they are applied to problem-solving in the real world (Sanders, 2009).

STEM education is therefore a model that ought to promote and improve learning of the disciplines that its acronym represents. So, science education practices are directed towards increasing pupil and student exposure to science, engineering and technology experimentation, especially in elementary grades (NRC, 2012, 2014; EC, 2015).

Effective STEM education has to center on interest and experience in early childhood, building new knowledge on the basis of what young children already know and advancing rich and exciting scientific experiences (NRC, 2012), without forgetting that, during schooling, STEM proposals have to help pupils achieve integral development.

It is worth stressing that in recent years, an A (Art) has also been added, spelling STEAM, widely defended as a multi- and trans-disciplinary approach aiming at the solution of socially relevant problems through innovation and creativity. The goal of this approach is to prepare students to solve the world's pressing issues through innovation, creativity, critical thinking, effective communication, collaboration, and ultimately new knowledge (Quigley & Herro, 2016, p. 410). A number of efforts have been documented that are consistent with these policy recommendations (see Bybee, 2013; NRC, 2012).



WHAT DOES EACH OF THE LETTERS REPRESENT?

S

“Science is the study of the natural world, including the laws of nature associated with physics, chemistry, biology and geology and the treatment or application of facts, principles, or concepts associated with these disciplines. Science is at the same time a body of knowledge that has been accumulated over time and a process - scientific research - that generates new knowledge. The knowledge of science lays the foundations of the engineering design process” (NRC, 2009).

In terms of literacy, the Program for International Assessment (PISA) defines scientific literacy as an understanding of the contexts, competencies, knowledge and attitudes that future citizens would need to “engage in science-related issues, and with the ideas of science, as a constructive, concerned, and reflective citizen” (OECD, 2006).

The teaching of science within the STEM approach, which may be useful to achieve scientific literacy, differs significantly from traditional teaching. It must promote, from early childhood, the development of skills that allow kids to reach scientific competence. It should therefore be strongly focused on problem-oriented inquiry-type experimental activity, experimentation that involves planning, designing and hands-on activities, preferably within an explicit theoretical framework. In addition, it also requires a teaching style that revolves around certain key ideas, indispensable for children to understand, enjoy, and marvel at the natural world (Harlen, 2010). Part of the solution to an overcrowded and fragmented science curriculum, often not sufficiently interesting for students, is to conceive scientific objectives during the compulsory stages of education, not in terms of knowledge of a set of facts and theories, but as a progression towards the understanding of key ideas - ‘big ideas’ - of relevance to the lives of students during and beyond the school. These ideas, from and about the sciences, appear in Annex 1. For example, working with gears, inclined planes, magnets and electricity would help kids in the development of their understanding that objects can affect other objects at a distance and that changing the path of movement of an object means that a net force has to act upon it.

T

“Technology, although it is not a discipline in the strict sense, includes the entire system of people and organizations, knowledge, processes and devices that go into the creation and operation of technological devices, as well as the artefacts themselves. Throughout history, humans have created technology to meet our needs and desires. Much of modern technology is a product of science and engineering, and technological tools are used in both fields” (NRC, 2009).

Technology is therefore the broad array of products and processes of our human-built world, not only associated with personal computers and the Internet. In terms of literacy, “technological literacy” refers to one’s ability to use, manage, evaluate, and understand technology (International Technology Education Association, 2002). So, in order to become a technologically literate citizen, a person should understand what technology is, how it works, how it shapes society and in turn how society shapes it.

With less development and importance in the curriculum than Mathematics or Science, technology-related education has handicrafts as an antecedent and is internationally interpreted in several different ways. The approach adopted in this project, in consonance with the definition of technological literacy, refers to learning among children of the use of the tools that scientific professionals, mathematicians and engineers, employ. In the real world, these tools include a wide variety of instruments: from scales used to measure the volume or mass of substances, to microscopes and telescopes used to study very small and very distant objects, to supercomputers used to model complex phenomena such as climate and particle accelerators that reveal the smallest blocks of matter. In this sense, children must learn to take data with appropriate tools (scales, tape measures, dynamometers, thermometers, chronometers, microscopes, test tubes, etc.) as well as the necessary tools to analyze such data (spreadsheets) and to present them (word processors). Through these activities, children should understand how technology shapes and is shaped by society.

In addition, a technological education adapted to current times should include programming and robotics. The use of robots, physical programming, virtual reality, animations, etc. encourages the development of computational thinking. This topic will be broadly addressed later on.

E

“Engineering is the systematic and often iterative approach to designing objects, processes, and systems to meet human needs and wants... Engineering is both a body of knowledge about the design and creation of man-made products, and a process to solve problems. This process is carried out under certain restrictions. A restriction in engineering design is the laws of nature or science. Other restrictions include time, money, available materials, ergonomics, environmental regulations and the possibility of building and repairing them. Engineering uses concepts of science and mathematics and technological tools” (NRC, 2009).

The newest and least developed component of the STEM quartet at the level of compulsory education is engineering. Its footprint in primary and secondary schools is much smaller than those in mathematics, science or technology. Its history in the United States, the country that has perhaps been incorporating engineering into its primary and secondary school plans longer than any other, stretches back only 15-years. Engineering education allows students to develop some specific skills, such as defining and developing devices or solutions for real-world problems. It is a vehicle to facilitate the understanding of the scientific ideas when applying them to solve engineering problems. For example, designing a toy car to meet a specific performance challenge can provide a context to develop or extend students’ understanding of force and motion.

It also helps students to recognize how science affects their lives and society through engineering and technology. Understanding these effects gives science relevance and makes learning more meaningful for many students. Finally, it allows students to acquire some key concepts, such as the design process, efficiency, and the limitations or restrictions (material, monetary, environmental, etc.) that affect any engineering solution to any real-life problem.

M

Mathematical literacy is defined in the Programme for International Student Assessment (PISA) as *“the capacity to identify, understand and engage in mathematics, and to make well-founded judgements about the role that mathematics plays in an individual’s current and future private life, occupational life, social life with peers and relatives, and life as a constructive, concerned and reflective citizen”* (OECD, 2002).

Mathematics can be defined as the study of patterns and relationships between quantities, numbers and space. Specific conceptual categories of primary mathematics include numbers and arithmetic, geometry, statistics, and probability.

Mathematics occupies a central place in all the “letters” that we have defined above. However, the way it is taught in school means that it is often perceived as a subject with no relation or at least a limited one with the real world. Integrating mathematics into STEAM proposals allows it to be revalued by students as central elements of scientific and technological work, and always present in real life. Using integrated STEM proposals, practically all the contents of pre-primary and primary school curriculum in the area of Mathematics can be addressed and, in addition, better understood by the students. These contents, for example, include measurement systems. The use of measuring instruments in investigations (for example, rules, scales, chronometers), helps kids to acquire the true meaning of the different units, as well as the need for transformations. Something similar happens with the representation of data.

As may be seen, STEM literacy involves interrelated competencies, that are intertwined and overlapping, and often, drive each other forward.

INTEGRATIVE STEM

An important point addressed in the STEM proposals is that all aspects should be addressed in an integrated way. But what does that mean? How can integrative STEM be achieved?

The integration can be done in several ways. Gresnigt et al. (2014), after analyzing several integrated STEM projects in primary school, proposed five different kinds, of increasing degrees of integration.

(See Figure 1; examples are ours).

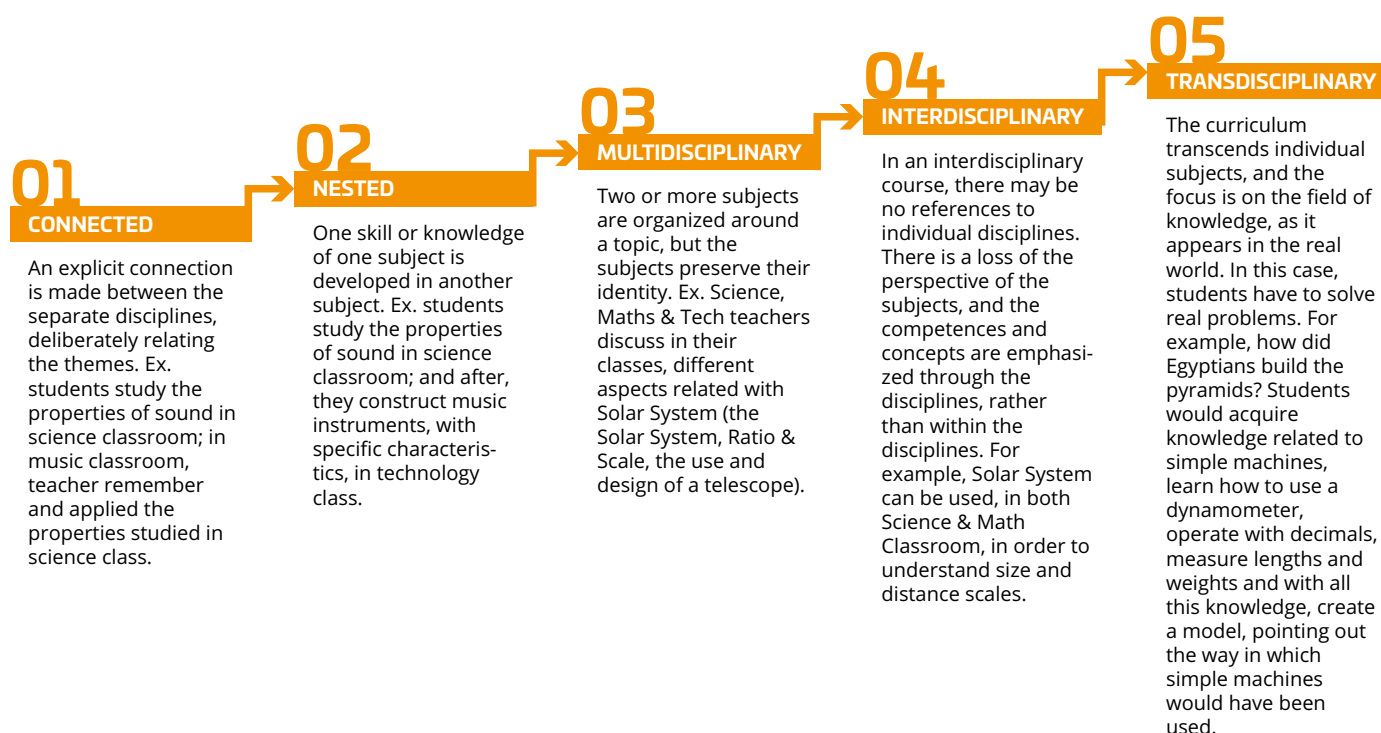


Figure 1 - Examples are ours.



We consider that integrative STEM education is more pertinent and viable for elementary school, because teachers teach most of the subjects to the same class. So, interdisciplinary and multidisciplinary treatments would not be a drastic change in elementary school and early-years education. In goal-directed preschool, an integrated STEM approach fits in well with the didactics of early childhood education that is at present applied in the classroom. Teachers need to be carriers of both knowledge of the content and updated skills on how to generate situations that support the learning of their students (Fleer & Pramling 2015; Thulin & Redfors 2016). *"The challenge goes beyond content knowledge to teacher beliefs and pedagogy practices"* (Fleer 2009 p. 1074). Teachers' attitudes to the content area is important; as Fleer et al. (2014) showed, teachers have unique possibilities with a 'scientific attitude', which fits in well with integrated STEM.

METHODOLOGIES AND CONSEQUENCES

Two methodologies

Integrated STEM proposals need to apply certain active, dynamic methodologies. Two methodologies that fulfil the requirements of integrated approaches are inquiry teaching and engineering design methodologies.

1. INQUIRY TEACHING

In the 2015 Report of the Expert Group to the European Commission on Science Education for Responsible Citizenship, the inquiry-based teaching methodology is proposed as one of the most advantageous for 21st century competences. In fact, several European projects have adopted this approach for science teaching, developing plenty of teaching materials, although mostly for upper primary and secondary-school levels, e.g. projects such as Profiles, Fibonacci, Sails, Primas, Parrise, and Engaged¹.

Inquiry teaching can be defined as a set of activities that seek to assimilate the learning of science and the processes and strategies that scientists follow to resolve problems in real-world situations. It is a strategy that seeks to facilitate self-learning through students' interactions with the objects of the environment that stimulate them, awaken their curiosity, and drive the development of higher-order thoughts and problem-solving skills.

Inquiry-based teaching should involve activities that include the analysis of scientific questions through the use and development of numerous skills (identification of variables related to the problem that needs to be investigated; design and realization of experiments; data interpretation; development of explanations, and the communications of results and conclusions). This cycle is shown in *Figure 2*.

Research suggests that young children can follow this methodology. But some adjustments have to be made, especially with the first part of the inquiry cycle. Inquiry is about questions, but it is difficult for kids to ask questions about something they have neither seen, nor touched, nor experienced. So, it is very important for young children first to engage, notice, wonder and question (Chalufour & Worth, 2004). That is, to give time to play in a scientifically stimulating environment. As many of the emergent questions may not be investigated, the role of the teacher is to focus observation and to clarify questions. After that, children can, with teacher support, follow the other stages.

Martin-Hansen (2002) distinguished three types of inquiry. Open student-centered inquiry begins with a student's question, followed by the groups of students designing, conducting and communicating the results of an investigation. Conversely, there is guided inquiry, in which the teacher helps students develop inquiry investigations in the classroom (usually, the teacher chooses the question for investigation and, sometimes, also the design of the experiments). In between, we can find the coupled inquiry, combining a guided-inquiry with an open one. It is useful with guided inquiry to target a particular concept, idea or standard, since the teacher is the one who chooses the question to be

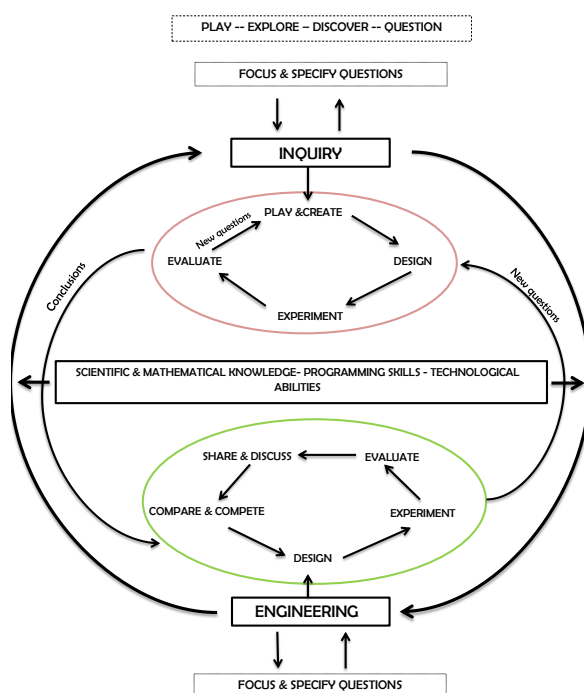


Figure 2 - Phases of inquiry teaching and engineering design for young children. Inspired in Chalufour & Worth (p.74, 2004) diagram.

¹The following websites of these EU projects have very interesting examples and downloadable pedagogic resources.

- **Profiles:** <http://www.profiles-project.eu>
- **Fibonacci:** <http://www.fibonacci-project.eu>
- **Sails:** <http://www.sails-project.eu>
- **Primas:** <http://primas.mathshell.org/pd.htm>
- **Parrise:** <https://www.parrise.eu>
- **Engage:** <https://www.engagingscience.eu/en>

investigated. The type of combination, length and depth of these investigations will vary taking into account ages and themes.

2. ENGINEERING DESIGN

Most engineering designs can be classified as inventions: devices or systems that are created by human effort and that did not exist before or that are improvements on existing devices or systems. Inventions are the result of joining technologies to meet human needs and to solve problems. A design is often the result of trying to do a task faster or more efficiently.

Engineering design methodology is, basically, like inquiry teaching, a methodology for problem solving. In the case of engineering design, the problems are of an open nature, which means that they have more than one correct solution. In addition, they are always subject to certain restrictions or specifications.

Engineering encourages children to apply what they know about science and maths—and their learning is enhanced as a result. At the same time, because engineering activities are based on real-world technologies and problems, they help children to see how disciplines like maths and science are relevant to their lives.

The use of this methodology when working with children means they have to learn to:

1. Define the problem.
2. Gather relevant information.
3. Generate multiple solutions.
4. Analyse and select a solution.
5. Test and implement the solution.

Research suggests that engineering activities help build classroom equity. The engineering design process removes the stigma from failure; instead, failure is an important part of the problem-solving process and a positive way to learn. It is equally important that there is no single “right” answer in engineering; one problem can have many solutions. When classroom instruction includes engineering, all students can see themselves as successful.

Engineering design for very young children can be a starting point to study the most amazing natural facts. As groups of students work together to answer questions like, “how should we design a package for transporting a plant?” they collaborate, think critically and creatively, and communicate with one another. During the process of designing, or after it, the teacher can develop an inquiry into the living conditions for plants. Also, engineering design can be used when a bundle of knowledge has previously been unpacked in class (using inquiry-based teaching or another active methodology) and the aim is for children to apply that knowledge, so that they understand it better. For example, after having seen various heat transmission methods, students can be asked to design a system, with everyday materials, to keep the water cold. In order to understand the nature of the knowledge generated in Engineering, it is important, that the solutions contain limitations. In the aforementioned case, it may be that they can only use two materials from those available, that the total cost does not exceed a certain amount, or that it is made with recyclable material. In addition, students have to justify their design with scientific arguments and to propose improved versions also based on available knowledge (previously worked).

REFLECTION

All methodologies imply reflection, an implicit process that occurs whenever we re-use ideas. It includes both retrospective and prospective self-assessment processes where one analyzes progress relating to goals or plans the next steps. This process can refer to abstract goals such as comparing one’s



current understanding to a target understanding, and to concrete goals such as analyzing whether one has collected evidence that can be used to support an argument. Both of these retrospective and prospective assessment processes can occur during the completion of a task or when a phase of the task has been completed. Learners vary in the degree to which they spontaneously engage in reflection. Thus, it is important to encourage and to support reflection and teachers should dedicate time to such activities (that can be done either individually or collectively; through either open or closed activities).

COLLABORATION

Collaboration is an essential part of an integrative STEM approach to teaching and learning. It is a key part of the educational experiences we aim to cultivate, due to its potential effectiveness for learning and productivity. We distinguish between collaboration and cooperation. Collaboration emphasizes joint participation in the task, intellectual interdependence, and the co-construction of knowledge, whereas cooperation emphasizes task distribution and often involves isolated individual contributions that are later synthesized to form a single product or outcome. In collaborative work it is difficult and at times impossible to identify the individual contributions in the final products.

Collaboration demands careful preparation, because some students may not view peer-interaction or group work as a form of viable learning at all, but as a game. Effective communication in peer interaction also involves shared norms regarding turn-taking; shared perceptions of the appropriate amount of overlap in verbal contributions and shared norms for the acceptance of different point of views, to reach consensus and continue onwards.

It is worth stressing that integrative STEM approaches require collaboration not only between children but also with teachers. Teachers, especially in the co-teaching of younger children, need to establish a mutual understanding among themselves of theoretical explanatory models and based on that understanding, they ascertain a mutual relation with the children, characterized by inter-subjectivity which includes both the child's perspective and the object of learning. By doing so, the role of the teacher is to support the process by creating a "bridge" between the child's previous experiences and the new focus of knowledge (Thulin & Redfors, 2016).

AN EXAMPLE FOR A MULTIDISCIPLINARY APPROACH USING INQUIRY TEACHING METHODOLOGY

Here, we present a multidisciplinary model for integration, based on a coupled inquiry (Martin-Hansen, 2002) that combines a guided and an open inquiry investigation (See Table 1). It begins with an invitation to inquiry in which the teacher selects an initial problem to investigate that is connected to a specific science standard or content. Next, an open-inquiry is implemented where students generate questions related to the first problem and *"specific concepts can be explored in a more didactic fashion allowing students to connect their concrete experiences to abstract concepts"* (Martin-Hansen, 2002, p.35).

COUPLED INQUIRY	STEM DISCIPLINES	STRATEGIES FOR INCLUSIVE STEM (SCUTT ET AL, 2013)*
INQUIRY INVITATION Science content is introduced through a real world problem.	SCIENCE - ENGINEERING Real world problem related to an engineering challenge.	• Promote active expert roles for girls. • Emphasize communication. • Demonstrate and encourage resilience. • Re-evaluate group work practices. • Clarity in grading policies and constructive feedback.
GUIDED INQUIRY Students perform guided experiment following teacher instruction.	SCIENCE Application of scientific methodologies, in order to address the scientific concepts needed to solve the problem. MATHEMATICS Data analysis and interpretation. TECHNOLOGY Handling of devices and instruments for the design of experiments, data gathering and analysis.	
OPEN INQUIRY Students keep addressing the initial problem through experiments that are not guided by the teacher.	SCIENCE, TECHNOLOGY, ENGINEERING, MATHEMATICS Students discuss the results obtained and they identify better ways to improve their design in order to solve the initial problem.	
INQUIRY RESOLUTION Solving the initial problem.	ENGINEERING Students design or implement the technological device that solves the initial problem, using the previously developed scientific concepts, thereby linking engineering and science. TECHNOLOGY Students propose possible technological applications in real world situations of the scientific concepts addressed throughout the inquiry.	
ASSESSMENT Communicate results.	SCIENCE, TECHNOLOGY, ENGINEERING, MATHEMATICS Students communicate their results and offer a possible resolution of the initial problem. The teacher evaluate the use of STEM disciplines: • Science (understanding of the scientific concepts and the inquiry skills acquired). • Engineering (use of the engineering design process and the solutions developed). • Mathematics (understanding of the mathematical concepts needed for analyzing and interpreting the data). • Technology (use of instruments and ICT devices and the application of the technology to the initial problem).	

Table 1: Relations between the coupled-inquiry phases (Martin Hansen, 2002), the STEM disciplines and the strategies for inclusive STEM (Scutt et al, 2013) (From Toma & Greca, 2018).

* Note that these strategies are common to all phases and that they are developed gradually throughout the whole process.

WHY INQUIRY TEACHING OR ENGINEERING DESIGN METHODOLOGIES FOR AN INCLUSIVE GENDER APPROACH?

Since Marie Curie in 1903, only 17 women have won a Nobel Prize in physics, chemistry or medicine, compared to 572 men. Today, only 28% of all of the world's researchers are women. Such huge disparities, such deep inequality, does not happen by chance. Too many girls are held back by discrimination, biases, social norms and expectations that influence the quality of education they receive and the subjects they study. (Cracking the code—Unesco report, 2017¹)

Teaching strategies within the classroom need to change, in order to narrow this gap and to improve the performance of girls, so that different support is given to female learners. Evidence suggests that gender-balanced curricula have to be contextualized to account of the interests of girls, have to link abstract concepts with real-life situations, and use hands-on activities. The Unesco report highlighted that *“Specific teaching strategies have been shown particularly to help girls and to reduce the gender gap in STEM achievement, while being beneficial for all students. These include, for example, student-centred, inquiry-based and participatory strategies, as well as strategies that improve girls' self-confidence and take account of their specific interests and learning styles”*. To this list, we can also add engineering design methodology and other useful methodology, since they emphasize the use of scientific concepts to find solutions to real-life problems.

Nevertheless, as stressed above in Table 1, complementary strategies should be adopted, such as encouraging the participation of girls and communication, and reviewing group work to encourage girls to adopt an active role. Likewise, the role models of female engineers and scientists in the field in which the students are working could also be used.

PROGRAMMING AND COMPUTATIONAL THINKING

In 2006, Jeannette Wing published, *Computational Thinking*, an article that caught the attention of many researchers. According to Wing (2006), computational thinking is a problem-solving skill-set rooted in computer science. The skill-set comprises problem solving, designing systems and understanding human behavior. Computational thinking represents a type of analytical thinking and, according to Wing, it is an attitude applicable to everybody, not just computer scientists. Generic skills like identifying patterns, breaking apart complex problems into smaller steps, organizing a series of steps to provide solutions etc. are all put forward. Marina Umaschi Bers, in her book *Coding as a playground*, proposed computational thinking as a means of expression and communication and drawing on the concept of literacy, she compared it with strategies for teaching a new language (Bers 2018). Focusing on expression and creation, rather than on problem-solving alone, we need tools that enable the creation of an external artifact. We need a language for expression.

Coding is a verb, not a noun. Coding is the action of putting together sequences of instructions and debugging or problem solving when things do not work out as expected. Coding is often described as the new language of the digital society increasingly structured by computers. Just as we do not teach kids to write in order to make them professional writers (e.g. novelists or journalists), we hardly expect every child to become a professional computer programmer by teaching coding. Everybody needs to write in order to express themselves and everybody needs to understand coding, in order to be able to interact in a culture and society heavily influenced by computer systems. Teaching children to code gives them fluency in a set of tools for self-expression. Coding with robots shows children that they can create with technology. Coding engages children as producers and not merely as consumers of technology (Bers 2018).

Coding has also been described as a new literacy for the twenty-first century. Coding enables new ways of thinking, communicating and expressing ideas. Literacy ensures participation in decision-making processes and engagement in power structures. Will those who cannot think in computational ways and who do not understand code be left out (Bers 2018).

¹ <http://unesdoc.unesco.org/images/0025/002534/253479e.pdf>

Powerful ideas in coding: In her book, *Coding as a playground* (Bers 2018), Marina Bers suggested seven powerful ideas for early childhood computational thinking:

- **Algorithms:** a series of ordered steps sequentially followed to solve a problem. Sequencing and understanding abstraction are central to understanding algorithms and its practice goes beyond computational thinking e.g. number of steps involved in tying shoes. Identifying what constitutes a step in the sequence is a matter of abstraction.
- **Modularity:** breaking down tasks or procedures into simpler units, engaging in decomposition. This can be practices without computers e.g. the task of having a birthday party. What tasks are involved? How detailed should the tasks be described? Inviting guests could for example be broken down further.
- **Control structures:** the order in which instructions are followed or implemented. More advanced examples of control structures are repeat functions, loops, conditional events and nested structures. But the key issue in the early childhood is familiarization with patterns and realizing the relationship between cause and effect e.g. when clicking the mouse, x does y, or when the robot detects light through its light sensor the robot should beep.
- **Representation:** order and manipulate data and values in different ways. Concepts can be represented by symbols e.g. letters can represent sounds, numbers can represent quantities, programming instructions can represent behaviors. Different types of things have different types of attributes e.g. cats have whiskers. And data types have different functionalities e.g. numbers can be added, letters can be strung together. In coding, we need to understand that programming languages use symbols to represent actions.
- **Hardware/software:** computing systems need hardware and software to operate. The software provides instructions to the hardware. Robots are mainly visible hardware but some components might be hidden e.g. circuit boards. Children need to understand that hardware is programmed to perform a task and that many devices can be programmed, not just computers.

These five powerful ideas have their origin in computer science and are all strongly linked to foundational concepts in early childhood education. But Bers put forward two more powerful ideas concerning processes and habits of mind; debugging and the design process.

- **Design process:** an iterative process used to develop programs and tangible artifacts. Bers suggests a series of steps defining a design process adapted for children. The design process is a cycle: there is no official starting or ending point. The steps are: ask, imagine, plan, create, test, improve, and share.
- **Debugging:** allows us to fix our programs using testing, logical thinking and problem solving. Once children understand how to debug their systems, they start to develop common troubleshooting strategies that can be used on a variety of computing systems. Things do not just happen to work at the first attempt, but many iterations are usually necessary to get it right.

ROBOTS AND ROBOTICS

Robots are increasingly finding their way into classrooms around the world not only to prepare students for a workplace that will almost certainly be dominated by technology, but also because it gives them extra motivation to focus on their studies. The European Commission has recognized the importance of robotics in Education and is actively supporting events such as the “European Robotics Week” (https://www.eu-robotics.net/robotics_week/). We should therefore prepare the next generation for the future, and involve them in robotics and coding from early stages.

Educational robotics activities may be diverse, both from the point of view of the robotic tools, but also from the point of view of the learning activities proposed to the learners. Hence, programming and robotics could, in fact, be considered as transversal tools, since students can learn to program while learning about other specific subjects at the same time. For example, students could program a robotic movement to identify different families in the animal kingdom. When designing, constructing, and programming, students learn how technology works and, at the same time, they apply the skills and content knowledge learned in school in didactic and exciting ways.

According to Eguchi (2014), educational robotics is rich with opportunities to integrate not only STEM but also many other disciplines, including literacy, social studies, dance, music and art, while

giving pupils the opportunity to find new ways to work together to foster collaborative skills, express themselves using the technological tool, problem-solve, and think critically and in innovative ways.

Enhancing the robotics experience means that the pupils involve themselves in activities where they can touch robots and gadgets, program them and manipulate them. Touching is very important at this learning stage. Kids learn better by manipulating and seeing the results of their work in real time.

There are also various class activities when learning with educational robotics where some children are involved in a specific challenge. This leads to both cooperative learning and learning through the experiences of other children.

It is important to emphasize that teachers should teach robotics as a game, especially in the early stages (3, 4 and 5 years old). Having fun not only helps the children to learn about robotics and other academic fields, but a fun classroom even helps them to accomplish their goals without even realizing that they are doing so. Teachers have to set a challenge for the pupils to fulfill in a previously defined time. Teachers have to give clear instructions and encourage the pupils to think, test and arrive at a solution, in order to reach their goal.

Educational robotics can also be presented as a tool for inclusiveness. Pupils living with various disabilities need exposure to real world situations and should be given such opportunities early in their education to remain competitive in the global arena of Science, Technology, Engineering, and Maths (STEM). Educators who work with pupils with disabilities need new and exciting, accessible learning models that bring these pupils closer to real world learning scenarios and that open the doors for them to careers in science and technology. Despite a pupil's particular disability, all of them should have exposure to hands-on science and technology environments that prepare them for real world applications (Dorsey. R, Park C.H, Howard A.M., 2013).

For instance, Deaf and Hard-of-Hearing pupils live in a world dominated by sound, where most children learn new vocabulary and language in a natural way. They are at a disadvantage in the hearing world, but when learning coding and programming they are talking a universal language that will help these pupils to complete all the steps that may be required.

Although a greater number of visual and auditory adaptations will be needed to interact with the robot or create it, making specific modifications will enable them to interact with their classroom companions and educators.

Robotics can be also a tool to prevent bullying. Robots and other technological devices are introduced as a means through which activities are expanded, as a subject/object outside the relational and emotional dynamics involving the pupils. The robot is a recognizable object, although it has a strong appeal and fascination for the pupils. More information at <http://www.roboticavsbullismo.net>.

Some video examples on how to use robotics in class <https://www.youtube.com/watch?v=BgkmGYbXrK4> (Learning about robotics and programming with Next 1.0 and how to combine it with other disciplines) and <http://ase.tufts.edu/DevTech/ReadyForRobotics/index.asp> (Educational Robotics kits with Kibo).

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Appendix A. Big Ideas in Science

SCIENCE

In Harlen (2015), the author concluded that big ideas should:

- have explanatory power in relation to a large number of objects, events and phenomena that are encountered by pupils in their lives during and after their school years;
- provide a basis for understanding issues, such as the use of energy, involved in making decisions that affect the health and wellbeing of both the learners and others, as well as the environment;
- lead to enjoyment and satisfaction when able to answer or find answers to the kinds of questions that people ask about themselves and the natural world;
- have cultural significance - for instance, affecting views of the human condition - reflecting achievements in the history of science, drawing inspiration from the study of nature and the impact of anthropogenic activity on the environment (Harlen, 2015, p. 14).

IDEAS OF SCIENCE

- All matter in the Universe is made of very small particles.
- Objects can affect other objects at a distance.
- Changing the path of movement of an object means that a net force has to act upon it.
- The total amount of energy in the Universe is always the same, but can be transferred from one energy store to another during an event.
- The composition of the Earth and its atmosphere and the processes occurring within them shape the Earth's surface and its climate.
- Our Solar System is a very small part of one of billions of galaxies in the Universe.
- Organisms are organized on a cellular basis and have a finite life span.
- Organisms require a supply of energy and materials for which they often depend on, or compete with, other organisms.
- Genetic information is passed down from one generation of organisms to another.
- The diversity of organisms, living and extinct, is the result of evolution.

IDEAS ABOUT SCIENCE

- Science is about finding the cause or causes of phenomena in the natural world.
- Scientific explanations, theories and models are those that best fit the evidence available at a particular time.
- The knowledge produced by science is used in engineering and technologies to create products to serve human ends.
- Scientific applications will often have ethical, social, economic and political implications (Harlen, 2015, p. 15-17).

03

GOOD PRACTICES

Good practices

A collection of good practices are summarized in the table below, described by name, age group, school subject, duration and locality. **The complete collection of good practices that has been developed can be found at www.botstem.eu**

The research has been done in the following countries: Spain, Portugal, UK, France, Cyprus, Nordic countries, Germany, Italy, Macedonia, Lithuania and Turkey. It is worth stressing that documented examples of teaching and learning practices for integrated STEM with robotics are scarce, which has made the search difficult, especially for the target ages of this project. Most of the practices found are extracurricular practices, developed in non-formal environments. However, integrated STEM activities appear to be starting, directed at older pupils and students in Secondary Education. It emerges from the interviews with experts that, in the case of robotics, teachers use what is available and easy to buy and use. Hence, activities are not necessarily guided by a framework methodology nor by specific teaching approaches.

TITLE OF THE ACTIVITY	AGE GROUP	SCHOOL SUBJECTS + OTHER TOPICS	DURATION	LOCALITY
The Hourglass race	3-4	S (physics), T	9 sessions: each approx. 15 mins.	Classroom, lab, outdoors, at home
The wind	3-5	S (physics), T, D (design),	6 sessions: each of 60 mins.	Classroom & outdoors
Program directions with Next 1.0	3-5	Robotics, maths	100 mins.	Classroom
Vibrating sound and music!	3-6	S (physics), music		
Snowman	3-7	Self-development	30 mins.	Preschool
Microplastics: small but deadly	3-16	S (chemistry, biology)	10 sessions	Classroom
Bluebot_Phy (Gravitation and friction)	4-5	S (physics, mechanics)	2 hours	Preschool
The colours	4-6	S (physics), T & D	2 sessions: each of 60 mins.	Classroom
KIBO_1	4-7	S, T, E, social aspects	Adaptable for learners	Classroom, lab, at home
Bluebot_Ma (Maths- and ABC-rugs)	4-8	T, M, swedish, social aspects	Adaptable for learners	Classroom, lab, outdoors, at home
Bluebot_Sci (The robot as a link in e.g. biology)	4-8	S (biology), T, social aspects	Adaptable for learners	Classroom, lab, outdoors, at home
Crystallography	4-11	S (physics, chemistry, geology), M	4 sessions: each of 90-mins.	Classroom
The body and the movement	5	S (anatomy)	6 phases	Classroom
Many flowers with ICT	5	S, M	3 classes	Classroom
Sound and light through cryptology and robotics	5	S (physics), M, language	2 sessions: each of 90-mins.	Computer lab, class, at home
Scribbling story	5-6	S, T, art	2 hours	Classroom

TITLE OF THE ACTIVITY	AGE GROUP	SCHOOL SUBJECTS + OTHER TOPICS	DURATION	LOCALITY
Testing Timers	5-7	T, M, design	60 mins.	Classroom, lab, outdoors, at home
Inseparables or not	5-7	S (physics), M	2 sessions: each of 60 mins.	Classroom
Senses	5-7	S	40 mins.	Classroom
Sources of light and shadow	5-7	S	40 mins.	Classroom, outside
Life cycles	5-7	S (biology)	Adaptable	Outside
Building with stones	5-8	S (physics), E, D & T	15 sessions: each of 50-mins.	Classroom & outdoor
Joint through Technology	5-15	T, E (coding and robotics)	6 sessions: each of 3 hrs.	Computer lab
Useless machines	6	T, drawing, italian	90 mins.	Classroom, lab, outdoors, at home
Adaptable Learning Graph for Maths	6	M	Adaptable for learners	Computer lab, class, at home
Beebots in stimulated recall of science content	6	S (biology), T	Adaptable for learners	Classroom, lab, outdoors, at home
Transforming family props into a Scratch game	6	T, art, portuguese language	90 mins.	Classroom, ICT room
High density cognitive paths	6-7	M	2 hrs.	Classroom
Geometry with MIND robot	6-7	M	90 mins.	Classroom
Robot DOC on the line of numbers	6-7	M	Adaptable to learners	Classroom
Getting clean drinking water	6-7	S	40 mins.	Classroom
Making an 'active' volcano	6-7	S	40 mins.	Classroom
Program directions, colors, sounds, halts with Next 2.0	6-7	robotics, sciences	100 mins.	Classroom
The sons	6-8	S (physics), M (music), & T	2 sessions: each of 60-mins.	Classroom
The vegetal biodiversity	6-8	S (biology), T, D	3 sessions: each of 60-mins.	Classroom & outdoor
A mysterious grot	6-8	S (physics), M, E	3 sessions: each of 60-mins.	Classroom
Learn Coding – Be a superhero	6-15	T, E (coding and robotics)	3 sessions: each of 60 mins.	Computer lab
From Poetry to Robotics	7	M, italian, english	3 lessons a' 30 min, 1 lesson a' 2 h	Classroom
Multiplication with the numbers 2, 3, 5 and 10	7	M	40 mins.	Classroom, hall, outside
Beat the flood	7-8	S (physics), E, art	2-3 sessions	Classroom, lab, outdoors, at home

TITLE OF THE ACTIVITY	AGE GROUP	SCHOOL SUBJECTS + OTHER TOPICS	DURATION	LOCALITY
Climate change activities for primary school	7-8	S (biology, chemistry), M, art	6 sessions	Classroom, lab, outdoors, at home
Bluebot_in_person (Children programming each other)	7-9	S, T, E, M, social aspects	Adaptable for learners	Classroom, lab, outdoors, at home
Bluebot_PhyMa (Friction and mathematics)	7-9	S (physics), T, E, M, social aspects	Adaptable for learners	Classroom, lab, outdoors, at home
Squashed tomatoes	7-10	S (physics), T, E, M	1 session, 2 hrs.	Classroom
Creating digital drawings with Python	8-10	T, art	90 mins.	Classroom, ICT room
Talent viewer	9-12	art, gender, communication, creativity	8 sessions: each of 45 mins.	Classroom

Now you will find some examples of good practices, but remember that the complete collection of good practices that has been developed can be found at www.botstem.eu.

Programming movements/directions with Next 1.0: Identify geometrical shapes, colors and sizes.

ORIGIN OF THE ACTIVITY

Sirabun Project is a project for children aged 3-5 years old within Next Robotics Edelvives. It is an opportunity for children to put into practice the numbers, geometrical shapes, animal kingdoms, linguistics, etc., they are learning at that stage and to apply those concepts to the robot, in order to program movements to achieve a concrete challenge.

SHORT DESCRIPTION OF THE ACTIVITY

Pupils from 3-to-5 years old are given the specific mission of identifying geometrical shapes, sizes and colors and programming Next 1.0 (a robot) to achieve the challenges as they are defined.

They will have to understand the concepts of this specific topic and program Next 1.0 commands, in order to make Next 1.0 move and reach the correct place for a positive outcome to the challenge. The teacher has a didactic guide to follow the progress of each challenge.

The pupils will, in order to achieve the defined challenges, have to:

- Read the challenge.
- Identify, on the mat, the Next 1.0 start and end points.
- Represent the Next 1.0 route using the programming cards, taking into account the steps Next 1.0 has to follow.
- Put Next 1.0 on the mat and program it using the buttons on its head, so that it moves to the exact programmed place.

A Practical example: Identify geometrical shapes, colors and sizes:

- The teacher poses several questions to the pupils: *How many sides does a triangle have? How many sides does a square have? What is the difference between a square and a triangle? Does a circle have two sides or corners?*
- From that point on new challenges start. Pupils will have to identify the different geometrical shapes, colors and sizes on the mat and program Next 1.0 according to the sequences that are required.

“



AGE OF THE PUPILS

3-5 years old.

DURATION

45 min.

PLACE

- Classroom.

SCHOOL SUBJECTS + TOPICS

CONCERNED

- Robotics.
- Programming.
- Maths.

EDUCATIONAL GOALS OF THE

PRACTICE

- Enhance the development of skills and abilities by fostering research, cooperative work, independence, solving challenges and critical analysis.
- Generation of strategies, logical understanding of things and abstract thinking.
- Acquire basic programming concepts.
- Get into programming directional language in a ludic and natural way.

TARGET GROUP

- Pupils in a class.

- Challenge 1:** Put Next 1.0 on the blue square and program it to go to the yellow circle.
- Challenge 2:** Put Next 1.0 on the yellow triangle and program it to go to the blue triangle.
- Challenge 3:** Put Next 1.0 on the red square and program it to go to the blue circle.
- Challenge 4:** Put Next 1.0 on the red circle and program it to go to other circles.
- Challenge 5:** Put Next 1.0 on the blue square and program it to go to other squares.
- Challenge 6:** Put Next 1.0 on the yellow triangle and program it to go to other triangles.
- Challenge 7:** Put Next 1.0 on the green rectangle and program it to go to other rectangles.
- Challenge 8:** Make Next 1.0 go from wherever the teachers indicates to:
- Medium-sized blue triangle.
 - Big yellow non-squared figure.
 - Small red square.
 - Medium-sized blue circular figure.

EVALUATION

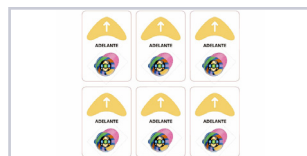
The pupils have to:

- Place Next 1.0 on the yellow circle and program it to go to the blue square without it passing over a red figure.
- Place Next 1.0 on the red circle and program it to go to another red figure without passing over a yellow figure.
- Place Next 1.0 on the green square and program it to go to another smaller squared figure. Now make it go to a small circle making sure that it will not pass over a blue figure.
- Working in teams, program a route so that Next 1.0 passes over 3 figures that meet the following requirements. Use the programming cards to create the sequence:
 1. Small green triangle.
 2. Big circular red figure.
 3. Small yellow non-squared figure.
 4. Big blue square.
 5. Medium-size green square.
 6. Medium-size blue circular figure.

MATERIALS / RESOURCES / TECHNICAL REQUIREMENTS



Workbook



Programming cards



Mat



Next 1.0

TIPS FOR EDUCATORS / THEORETICAL BACKGROUND (IF APPLICABLE) AND CURRICULUM CONTEXT

As part of the comprehensive Educational Robotics project for Young learners:

www.edelvives.com/pr/edelvives/robotica/indexEN.html

Video where you can see Next 1.0 interacting in a kids class:

<https://vimeo.com/162381994>

The Inquiry Processes of Pre-primary pupils: crystallography

ORIGIN OF THE ACTIVITY

Espiciencia was born in 2010, the brainchild of PhD. Barbara de Aymerich and the fruits of her teaching and research work in the rural world.

SHORT DESCRIPTION OF THE ACTIVITY

Visualizing a collection of minerals, we observe very different crystals, presenting different shapes and colors and everyone wishes to know why.

An experiment involving the crystallization of sodium chloride is then presented, in which the pupils learn the concept of solute and solvent, of saturated and supersaturated concentrations and are able to observe the cubic form of the crystals.

Afterwards, the process is studied more thoroughly, through several experiments in which different variables are changed, introducing the pupils to the inquiry-based process (we analyze the data and we draw conclusions by asking researchable questions, formulating our hypotheses, experimenting, and observing and compiling the results).

The dependent variables:

1. Compound to crystallize, solute (common salt, sugar, salts of Epson, borax, alum).
2. Solvent temperature (water at 15° C and water at 60° C).
3. Solvent (water, alcohol, oil).
4. Crystallization time (1, 2, 3 and 4 weeks).

Another very interesting part of the experience was its creative side, in which each pupil wished to give shape and color to the crystals, providing a good example of chemistry and art.

The experience ended with a field trip to observe a karst complex and its calcium carbonate concretions.

METHODOLOGY FOR CRYSTALS FORMATION

- Preparation of supersaturated solution of the solute (crystallizable compound) and solvent (water, alcohol, oil) selected at the temperature of the fixed solvent (10°C, 60°C).
- Filtration of the solution on filter paper (funnel).
- Let the solution stand in a petri dish or in a glass with a thread or pipe cleaner or sponge, in a flat place for the set time (1, 2, 3 or 4 weeks).



AGE OF THE PUPILS

4-11 years old.

DURATION

- 4 sessions.
- 1.5 hour per session.

PLACE

Espinosa de los Monteros (Burgos).

SCHOOL SUBJECTS + TOPICS

CONCERNED

- Chemistry.
- Physics.
- Geology.
- Creativity.
- Maths.

TARGET GROUP

- In all, 24 pupils. Divided into two groups of 12.
- In this activity, the parents work with their kids, and older students help the younger ones.

EVALUATION

The completed activity was evaluated from three different points of view:

- Kids
- Families
- Teachers

To do so, we conducted a fifth feedback session in which we passed a survey to parents, teachers and students on the development of the experience, in which we valued from 1 to 5 (1 unsatisfactory, 5 very satisfactory) the following items:

1. Did you like the practice?
2. Have you learned new concepts?
3. Would you know how to reproduce it at home?

MATERIALS / RESOURCES / TECHNICAL REQUIREMENTS

- Classroom with water, electricity and internet connection.

EQUIPMENT

- Mineral collection.
- Magnifying glasses.
- Glass tumblers.
- Spoons.
- Heat source (oven, small furnace,...).
- Heatable container.
- Funnels.
- Filter paper.
- Petri dishes.
- Sponges.
- Pipe cleaner.
- Clips.

REAGENTS

- Food dyes.
- Fluorescent marker.
- Water.
- Alcohol.
- Oil.
- Crystallizable chemical compounds (sodium chloride, white sugar, Epson salts, alum salts, borax).



EDUCATIONAL GOALS OF THE PRACTICE

1. Introduce the pupil to the inquiry-based scientific method: study the problem, setting different hypotheses, experimentation and results, verification of the proposed hypotheses and discussion and preparation of the conclusions.
2. Encourage the curiosity of the child for the world of science, stimulating their critical sense and logical-rational spirit.
3. Stimulate the participation of the family in the knowledge and practice of science as a driving vehicle for new vocations.
4. Introduce children to the elements of scientific experimentation such as materials, safety standards and protocols.
5. Know the geology of the area, specifying whether there are mineral deposits and their crystallography.

TIPS FOR EDUCATORS / THEORETICAL BACKGROUND (IF APPLICABLE) AND CURRICULUM CONTEXT

The rural environment is an ideal place for the development of STEAM activities, given its unique and easily accessible natural heritage and social resources.

The start-up of a school, of an educational project similar to ESPICIENCIA, is at first expensive given the idiosyncrasies of rural society, but it is immensely enriching and necessary to bring science and technology closer to families from small rural areas.

<http://www.espiciencia.com>

Joined through technology

ORIGIN OF THE ACTIVITY

The project “Joined Through Technology” was funded through Google RISE Awards after a successful proposal from the mathisis.org team. The coordinators, Alexandros Kofteros and Matina Marathefti, are both elementary school teachers. The aim of the project is to bring together kids from 5-15 and instructors from larger communities in Cyprus, Greece and Turkey, while learning robotics and programming. Teamwork and other social skills were to emerge, while cultivating love, peace, and respect.

The program was approved by the Minister of Education who also attended the opening of the first lessons.

SHORT DESCRIPTION OF THE ACTIVITY

Each lesson was divided in 2 workshops: Coding and robotics. Each lesson had a different topic. Children were divided according to their group age and they attended the activities of the 2 different workshops, with a short break, in between each session.

MATERIALS / RESOURCES / TECHNICAL REQUIREMENTS

Software and robotic kits:

- Run Marco.
- Light Bot.
- Scratch.
- Scratch junior.
- 3D printing.
- Robot Mouse.
- Engino.
- Lego WeDo2.
- Lego Mindstorms EV3.
- Meet Edison, etc.

Computer lab.



AGE OF THE PUPILS

5-15 years old.

DURATION

- 6 lessons (once a week from January – April 2017).
- 3 hours duration each.

PLACE

- Science & Space café Nicosia.

SCHOOL SUBJECTS + TOPICS CONCERNED

- Coding.
- Robotics.

EDUCATIONAL GOALS OF THE PRACTICE

- Learning goals: To promote coding using various programmes and software, as well as to develop STEAM concepts through educational robotics.
- Social goals: To fill the gap that was created due to political conditions between the two communities, by bringing together Turkish and Greek Cypriots children.

TARGET GROUP

- Children from both communities of Cyprus (Turkish and Greek Cypriots).
- Up to 20 children.

High density cognitive paths practicing geometry: creating paths and commands executable by a child or a robot

ORIGIN OF THE ACTIVITY

Caloi Serafino, a primary school teacher, from the province of Verona (Italy).

High-density cognitive paths are mathematical activities that develop the skill and the pleasure of mathematics;

They are designed and created to be practiced in schools, using the available materials and space, making the creation of feasible simple and effective learning opportunities possible that save time and energy.

The paths are part of the “Not one less” project with which we wish to design and create simple and effective learning pathways providing the best possible school, one that knows how to provide each pupil with the best chance of learning:

- Pupils who have just arrived in our country.
- Pupils who have learning difficulties.
- Pupils who travel regularly.
- Pupils who have attend school irregularly.
- Pupils who have no learning difficulties but are not very motivated.
- Pupils who have no learning difficulties and are highly motivated.

All of this is done to achieve the best school where every child, from the first to the last, can develop their potential and where everyone can learn while having fun.

SHORT DESCRIPTION OF THE ACTIVITY

Example for a class of 20 children:

- A floor with square tiles and paper tape are needed.
- The pictures show a possible sequence of work.
- Work can start on the floor or with a sheet, such as the one shown on the right, where a pupil writes down the commands to move something on the squares.
- Then the children work in small groups with different roles.
- A first group creates a route on a sheet and gives the commands to a second group that draws the route on the floor; then the two groups compare the outcome with the route that the first group had designed.



AGE OF THE PUPILS

6-7 years old.

DURATION

One or more 2-hour lessons.

PLACE

A floor with sufficiently large square tiles on which we can work with children; if the floor has no tiles, then the squares can be formed with ribbons or other materials on a normal linoleum floor.

SCHOOL SUBJECTS + TOPICS

CONCERNED

This activity concerns the ability to create routes on a squared surface.

EDUCATIONAL GOALS OF THE PRACTICE

Presentation and / or review of some geometrical concepts on squares and rotation.

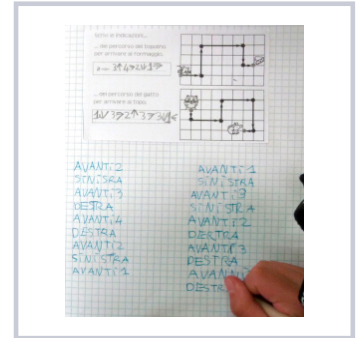
TARGET GROUP

- Class.

- Depending on the age and abilities of the children, it is possible to add more commands relating to rotation and directional changes, corners, grades...
- In further lessons, it is possible to implement this path with the use of robots and design various routes with them.

There are many possible variations:

- A first group draws a route on a sheet, than a second group programs the robot, measures the distances that can be introduced, as well as any angles and the robot can be programmed to follow routes in the shape of geometric figures.
- During this activity the children have to “create” a code, a language to program the routes.



EVALUATION

- This activity stimulates discussion and debate among children, so that they learn to use the precise terms of the geometry to find the solution to the problem when for example the path from design becomes complex.
- The activity also stimulates creativity when it is expected to develop a simple and comprehensible language for the commands.
- It assesses the ability to work in teams.
- This activity gives the teacher a chance to discuss the work done in class and thereby to go over such concepts as floor, path etc. in a significant way.

MATERIALS / RESOURCES / TECHNICAL REQUIREMENTS

- Floor with squared tiles.
- Paper tape.

TIPS FOR EDUCATORS / THEORETICAL BACKGROUND (IF APPLICABLE) OR CURRICULUM CONTEXT

- The activity is very simple to arrange and to carry out, but it has a high teaching yield both for the development and/or the review of geometrical concepts and for the development of specific skills relating to geometry and coding.
- The activity also helps children to develop a liking for mathematics.
- The task, very importantly, therefore allows every child, even those who have learning difficulties, to actively participate in the construction of their own learning.

Bluebots, physics and mathematics in primary school

ORIGIN OF THE ACTIVITY

Eva is a grade 1-7 teacher and has for the last 20 years been working with grades 1-3, in primary school.

She came across the Bluebots six-months ago and has since been using them regularly, in combination with a variety of school subjects, including language, maths, biology and physics. She stresses the importance for a teacher to think through the purpose of using the robots carefully, thereby avoiding what might otherwise become aimless play.

In the present exercise, the children work in groups of three and use the Bluebots to explore maths and the physical phenomenon of friction.

SHORT DESCRIPTION OF THE ACTIVITY

The children work in groups of three. The aim of the exercise is for the children to measure and compare how far the Bluebot can move forward in a certain time and on different materials. For this, they use a stop-watch and the bare floor, a rug, a stretched cloth, etc., and a ruler or a measuring tape.

The children program the Bluebot to move forward over those different materials and use the stop-watch to measure the desired time for it to move, such as for instance 30 seconds. After 30 seconds, the children stop the stop-watch and use the ruler or measuring tape to measure the distance the robot has moved.

They compare the distance over different materials and discuss the outcome in relation to the materials.

The textures are examined hands-on. How can they make the robot move faster or slower on a certain material?

MATERIALS / RESOURCES / TECHNICAL REQUIREMENTS

Bluebots, stop-watch, ruler/measuring tape, different floor covering materials such as a rug, a cloth, the bare floor.



AGE OF THE PUPILS

7-9 years old.

PLACE

- Classroom.
- Lab.
- Outdoors.
- At home, etc.

SCHOOL SUBJECTS + TOPICS

CONCERNED

- Science (friction and features of different material).
- Mathematics.
- Engineering in the terms of coding, but also social and democratic aspects of the curriculum, through group activities.

EDUCATIONAL GOALS OF THE

PRACTICE

Knowledge of friction and features of different material through exploring different ground material and their influence on an object's speed and distance.

Mathematics in terms of speed, distance, time and measuring. The coding aspect of programming.

04

NEW ACTIVITIES

Magnets



THE SCIENTIFIC METHOD

How can objects affect other objects at a distance?

TECHNOLOGY

THE ENGINEERING PROCESS

Let's design a magnetic toy!

MATHEMATICS

Classify, arrange in series and count to know the peculiarities of magnets.

ROBOTICS

Let's programme a simple robot to consolidate our learning!

CONCISE DESCRIPTION

Amazingly, there are objects which affect other objects at a distance! But this is not a magic trick, it is only a property of magnets. There are a lot of objects and gadgets around us with this characteristic from compasses to toys. In this unit, the children are encouraged to design and build one of those magnetic toys. They therefore have to generate their own knowledge about magnetism following Scientific Method and think critically and creatively, as engineers do, to design a prototype. The children have to apply mathematical knowledge, in order to achieve these goals, related to series, classifications, counting and programming skills to program a simple robot, which helps them to consolidate the new information.

THE SCIENTIFIC METHOD

PLAY & CREATE

At the beginning of the class, it is important to introduce the subject throughout a problematic situation. You must arouse children's interest and curiosity to know more about magnets. Here, you have an option:

<https://www.youtube.com/watch?v=XRxf2qvJTM>

Brainstorm with the pupils what a magnet is and what it is for. *What do you know about them? Do you use magnets in your daily routines? What for?* Their previous ideas must be the starting point.

Organize four separate areas where the pupils can play, explore and discover some features of the magnets related to the following questions:

- Area 1: What kind of things are attracted by magnets?
- Area 2: Can magnets attract each other?
- Area 3: Can magnets attract objects when there is a surface between them?
- Area 4: Do magnets have different power?

Once the groups are ready (four to five pupils in each group), it is crucial to support their own exploration asking them guiding questions which help them to acquire new information. Hence, some of the time has to be dedicated to each group while the others are exploring freely and use repetition until the content of the children's discussions and actions change. Do not forget to encourage them to explain and to share with their peers what they have just learnt. Language is an indispensable element



in the acquisition of significant knowledge.

It would be a good idea to distribute some visual worksheets adapted to the needs and abilities of learners where they can communicate what they have done through photos or drawings.

DESIGN-EXPERIMENT-EVALUATE

Once the pupils have become familiar with the available materials, observing what can be done with them and analyzing some of their features, it is time to conduct an experiment. Sitting down with each group and helping the children to organize the information gathered from observations and guiding them in the design of an experiment, will help solve the question that has been formulated in each area.

Encourage pupils to predict what will happen with magnets and, if you consider it appropriate, introduce the concept of hypothesis. Here are two possible predictions:

- Area 1: Magnets will attract the keys, but not the rubber.
- Area 2: Magnets can attract other magnets.



REMEMBER!

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis in keeping with their own experience. So hypotheses are neither right nor wrong, but only offer possible explanations of a certain event.

AREA 1 WHAT KIND OF THINGS ARE ATTRACTED BY MAGNETS?	AREA 2 CAN MAGNETS ATTRACT EACH OTHER?	AREA 3 CAN MAGNETS GO THROUGH SURFACES?	AREA 4 DO MAGNETS HAVE DIFFERENT POWERS?
What do you need to conduct the experiment? Magnets and a wide range of metallic and non-metallic objects. You can introduce containers with sand or stones mixed with different metal objects.	What do you need to conduct the experiment? Magnets with different sizes, shapes and weight.	What do you need to conduct the experiment? Magnets, paper, cardboard, wooden and plastic boards and buckets with water, among other options and magnetic objects.	What do you need to conduct the experiment? Magnets or different strengths and clips.
What do the children have to do? They have to classify the objects in two categories: Objects which are attracted by magnets and objects which are not.	What do the children have to do? They have to arrange magnets in series. At first, mark the magnet's polarity with red and blue stickers. After that, give them more magnets, but this time do not mark the polarity. Ask them to arrange them in series again.	What do the children have to do? They have to verify if magnets can attract objects when there is a surface between them and classify those materials.	What do the children have to do? They have to identify how many clips are attracted by magnets of different power. Try to use magnets which attract a number of clips that four year old children can understand. In this way they can also practice count and number; alternatively, they can make comparisons between quantities.
Make them think and reason! <i>Do those objects share any characteristic?</i>	Make them think and reason! <i>Which colors are attracted and which ones are repelled? Does every magnet react in the same way?</i>	Make them think and reason! <i>Can a magnet attract objects when they are separated by a surface? Is the thickness related to this phenomenon? Will you be able to invent a magic trick?</i>	Make them think and reason! <i>Do all the magnets attract the same number of clips? Will they find out some functional applications?</i>

SHARE & DISCUSS

Once the experiments are done and children have expressed their reasoning with regard to these concepts, it is time to express and share what they have just discovered and learnt. It is important to guide and help them with their answers, in order to enable them to acquire the right competencies for expressing and understanding scientific language.

On the one hand, at this point you can use a robot to consolidate their new knowledge. Ask them some questions related to magnets and let them program a robot to “find” the answer. This is a really good way to introduce children in simple programming. On the other hand, older children can show how magnets behave by “Stop Motion” technique where they can make drawings of vectors and field lines for different positioning of two permanent magnets. Here you have a good example of this technique:

<https://vimeo.com/40950441>

THE ENGINEERING PROCESS

It is time to design and build a magnetic toy. Start with a brainstorming session on the meaning of “engineering” and define what steps you have to follow. Keep the groups established and give them proper support to consolidate the new knowledge at each stage.

DESIGN-EXPERIMENT-EVALUATE

Show them different models of magnetic toys and start to ask questions about the design. *If you want to build a particular magnetic toy:*

- *What things do you have to consider?*
- *What do we want to build?*
- *What materials do we need?*
- *How will we build it?*
- *Which properties of the magnet do we have to take into account?*

Invite pupils to brainstorm about how to answer those questions and let them share their opinions and ideas. Here you have one possible option to build, but you can suggest any other.

In this step, children have to come up with an idea about what the magnetic toy will look like and take into account the answers to the questions listed above. Encourage them to be creative in their designs and praise their initiative.

Once the prototype is designed, the pupils have to gather the materials written in the images list attached to the model toy that was previously chosen.

Now, all hands on deck because it is time to paint, draw, cut, glue and... test it out!

Does the toy have a magnetic function? Is the toy able to attract its targets? Would you change any feature of the toy? With assistance, the children have to evaluate and improve on their prototypes; everything can be improved!

SHARE & DISCUSS

Let pupils show and explain their magnetic toy to their partners. They can tell why they chose this toy, how they have built it, how important the magnets are in the new toy and how they felt during the process and after finishing it, among other options.

COMPARE-COMPETE

Finally, let the children play with the designs of their partners and encourage them to compare each one highlighting those characteristics that they like the most and why. Receiving positive feedback from their peers will be the best reward.

“

WHAT DO YOU NEED?



A cardboard printed with different shapes (triangles, squares, circles, etc.), things (animals, people, etc.), numbers or letters.

Scissors, crayons, glue, cords, sticks and clips.

Changes of water



THE SCIENTIFIC METHOD

How does matter change?

TECHNOLOGY

Let's create a time-lapse video.

THE ENGINEERING PROCESS

Make an ice-lolly!

MATHEMATICS

Learn about measurement units and gadgets and ordinal numbers.

ROBOTICS

Let's programme a simple robot!

CONCISE DESCRIPTION

Understanding natural phenomena requires methodologies that let children experience the event; listening and imagining are not enough in themselves, children have to concretize this abstract knowledge and find a functional connection with their everyday routines. In this unit, the pupils will discover how matter changes under different conditions and how this knowledge is required to make an ice-lolly, using Scientific Method and the Engineering Design Process. This objective requires learning scientific concepts of states and changes of matter, learning to come to agreements and thinking critically and creatively, as engineers do, to design a perfect ice-lolly. In addition, children have to apply mathematical knowledge on counting, quantifiers and measurement gadgets, technological abilities to take photographs and they have to create a time-lapse movie and programming skills to program a simple robot.

THE SCIENTIFIC METHOD

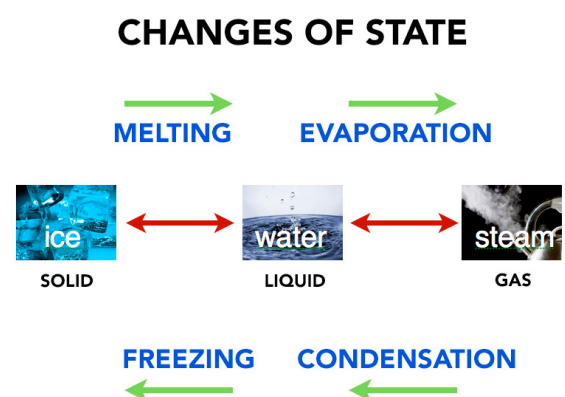
PLAY & CREATE

At the beginning of the class, it is important to create an appropriate atmosphere where the pupils are able to talk and share their opinions and experiences about the states of matter. Take advantage of that magnificent opportunity to identify how they perceive and interpret the world, in order to help them acquire more complex ways of thinking and understanding.

Set up small working groups and start talking about the states of matter (solid, liquid and gas), so as to identify how they connect this concept with their everyday world. Guide their comments with questions which will help them focus on the topic and express their ideas more deeply. *What does solid mean? Is it possible to find the same substance in solid, liquid and gas state? What does it depend on?* Moreover, show them different examples and ask the pupils to classify them and to compare them by their states.

DESIGN-EXPERIMENT-EVALUATE

Now it is time to conduct experiments to concretize the abstract concepts describing changes in the state of the matter. This step implies a definition of the problem that will lead to the Scientific Method,



will take into account the ideas from the discussion groups, and will raise more questions on the topic.

- *What will happen if we introduce water in the freezer?*
- *What will happen if we leave an ice cube in a sunny place?*
- *What will happen if we boil water?*

Encourage pupils to predict what will happen to the water when it is under certain conditions and, if you consider it appropriate, introduce the concept of hypothesis.

During the experiments, gradually introduce different scientific concepts such as temperature, solidification, fusion and evaporation, so that the pupils can name what they are watching.



REMEMBER!

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis in keeping with their own experience. So hypotheses are neither right nor wrong, but only offer possible explanations of a certain event.

FIRST EXPERIMENT MELTING		SECOND EXPERIMENT EVAPORATION		THIRD EXPERIMENT SOLIDIFICATION	
What do you need to conduct the experiment?		What do you need to conduct the experiment?		FIRST STEP	SECOND STEP
Two ice cubes, two containers (one located close to a heat source and the other away from it) and a camera.		Water and a stove.		What do you need to conduct the experiment? Ice trays with different shapes and water in liquid state.	What do you need to conduct the experiment? The cubes previously prepared by the pupils and a time-lapse video to illustrate the solidification process.
What do the children have to do? They have to draw, take photos and, at different points of the process, explain how the water appears and compare both cubes. Once the cubes are melted, it would be great to create a time-lapse movie with the photos or with their paintings to watch how ice cubes melt!		What do the children have to do? They have to pay attention and draw what they are watching.		What do the children have to do? They have to pour water in the ice trays with different shapes. <i>(The teacher will be the person in charge of placing them in a freezer).</i>	What do the children have to do? They have to analyze a time-lapse video previously created to show how the water has frozen guided by the questions from the teacher.
Make them think and reason! <i>What has happened to the water? Why has the water changed its state? Why do you think the cube closest to the radiator has melted before the other one?</i>		Make them think and reason! <i>What has happened to the water? Have you ever seen this process before? When? What is necessary to provoke this phenomenon?</i>		Make them think and reason! <i>Can water adopt different shapes? Why?</i>	Make them think and reason! <i>What has happened to the water? Why is it solid now? Can a triangle cube be placed in the square tray? Can ice adopt different shapes? Why?</i>

It would be interesting to include other common substances for children like wax.

SHARE & DISCUSS

Once the experiments are done and children have reasoned about these concepts, it is time to consolidate the knowledge acquired throughout the programmed activities in a playful and natural way.

At first, teach the children how to program a simple robot (Next 1.0 or Next 2.0), give them some indications and let them explore it for a while. When



Figure 3 - NEXT 2.0

they have become comfortable with the robots pose different challenges.

You can use a folder with different pictures taking into account the knowledge with which you wish to work.

Program the Robot to a square where you can see the water at room temperature. What do you call this water state?

Place the Robot over a square where the temperature of the water is low. What is the state of the water in this picture?

During this activity is important to guide and help children with their answers, so as to help them acquire the right competencies for expressing and understanding scientific language.

A version for older—using more complex programming tasks—can be found at: <https://www.edelvives.com/pr/edelvives/robotica/indexEN.html> or <http://botstem.eu/>



REMEMBER!

The Scientific Method is not a fixed sequence of steps, it is a dynamic process guided by six activities: cooperate, argue, debate, think, record and share.

THE ENGINEERING PROCESS

It is time to make an ice-lolly but before that, start with brainstorming about the meaning of “food engineering” and define what steps you have to follow. Keep the groups established and give them proper support to consolidate the new knowledge at each step.

DESIGN-EXPERIMENT-EVALUATE

It is important to learn how put questions. *If you want to make an ice-lolly,*

- *What are the main things you will have to consider?*
- *What will be the flavour of the ice lolly?*
- *What ingredients do we need?*
- *What are the steps to follow?*
- *How will its shape be?*

Invite pupils to brainstorm about the flavor and shape of the ice-lolly and let them share their opinions and ideas. Let each group choose from the ingredients and utensils that are available and decide what their ice-lolly is going to look like. Help them come to an agreement.

Give them a disorganized sequence of photographs about the steps to make an ice-lolly. (You can also create a folder and encourage the pupils to program an appropriate sequence for the robot to follow). Once all the groups have organized the photos, discuss with them the process where you can introduce the ordinal numbers.

Now, all hands on deck, because it is time to pour, mix, shake, freeze, and... taste it!

During the process you can work on counting and teach children what scales and measuring glasses are for and how they are used. Help them think about the process, in order to assimilate the knowledge acquired during the Scientific Method.

SHARE & DISCUSS

Encourage the pupils to show their creations and explain how they were made. They can share with their partners why they chose one flavor or another and how they came to an agreement, how they obtained that shape, how the liquid changed into solid and why they consider science and engineering important.

COMPARE-COMPETE

Finally, encourage the children to appreciate the ice-lollies of the other groups and to mold them with play dough and to draw the steps of the process, in order to show other people how to make an ice-lolly!

If you consider it appropriate, introduce other scientific concepts such as solutions and mixtures into this activity.

Inclined plane



THE SCIENTIFIC METHOD

What is an inclined plane?

TECHNOLOGY

Spread your knowledge by Scratch.

THE ENGINEERING PROCESS

Let's design a proper road!

MATHEMATICS

Measure the length of the road and the time spend by the robot to reach the top.

ROBOTICS

Let's programme a simple robot to reach the top of the road!

CONCISE DESCRIPTION

Simple machines have been making our lives easier and more comfortable for centuries. The inclined plane is one the most common ones and we use it almost every day! In this unit, the pupils are invited to design and build a road that will let people visit a magnificent newly-found cave. Hence, they have to think like scientists to identify how the length and surface of the road can affect the force required to reach the cave. Additionally, they have to become engineers and apply what they have discovered as scientists and build the road to reach the cave. With the aim of achieving these goals, our pupils have to apply their mathematical knowledge on measurement units and their technological abilities, to share what they have discovered, as well as their skills at programming a simple robot.

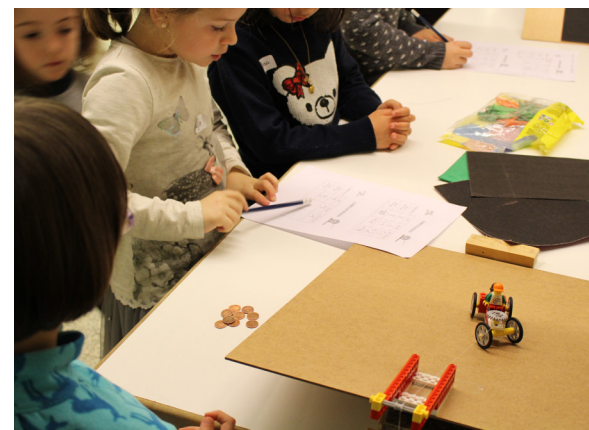
THE SCIENTIFIC METHOD

PLAY & CREATE

At the beginning of the class, you have to introduce the subject through a problematic situation and awaken children's interest and initiative, to find a solution to the following problem:

In a small village, a group of hikers have found a cave on a mountain top. The engineering department of the local council is examining ways for people to reach the cave and visit this spectacular discovery. With this purpose in mind, they have asked for your collaboration, in order to design a road, explaining which characteristics need to be included.

Organize working groups where pupils can play, explore the available materials (an inclined plain with different surfaces such as cardboard, acetate paper and sandpaper, and with different lengths, toy cars, a pulley and coins) and discover some of their features freely, but with significant teacher support. Dedicate enough time to each group while asking key questions and use repetition until the discourse and the actions of the children



REMEMBER!

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis in keeping with their own experience. So hypotheses are neither right nor wrong, but only offer possible explanations of a certain event.

change. Do not forget to encourage them to explain and share with their classmates what they observe. Remember, language is an indispensable element to acquire significant knowledge. It would be also a good idea to introduce some simple worksheets adapted to the needs and abilities of the learners.

DESIGN-EXPERIMENT-EVALUATE

After getting familiar with the available materials, observing what it can be done with them and analyzing some of their features, it is time to conduct an experiment. Get together with each group and help them organize the information gathered from observation and guide them to design an experiment in order to solve the question: *How can you build a road that people can walk up without a lot of effort?*

Introduce two variables:

- Variable 1: The length of the road
- Variable 2: The type of surface

Start with one of them and check that the new knowledge has been properly acquired; avoid overwhelming the children with too much information.

Encourage pupils to predict what will make it easier to reach the top of the mountain, keeping in mind the variables that have been proposed above. If you consider it appropriate, introduce the concept of hypothesis. Here are two possible predictions:

- With a plain surface you will be less tired.
- The shortest path means that the trip is shorter and not so hard.

In this case, due to the age of the children the concept of force will be represented by coins; the more coins the car needs to reach the top, the more force is required. However, a dynamometer can be used for older children.

VARIABLE 1 THE LENGTH OF THE ROAD	VARIABLE 2 THE TYPE OF SURFACE
What do you need to conduct the experiment? An inclined plane, ramps with different lengths, but of the same surface, a pulley, a toy car, and coins.	What do you need to conduct the experiment? An inclined plane, ramps with different surfaces (e.g.: cardboard, acetate paper and sandpaper) but of the same length, a pulley, a toy car and coins.
What do the children have to do? They have to change the ramps of the inclined plane and count how many coins the car needs to reach the top of the road.	What do the children have to do? They have to change the surfaces of the ramp and count how many coins the car needs to reach the top of the road.
Make them think about their experiences <i>When do you feel more tired, when you go up a short steep slope or a mild long one?</i>	Make them think about their experiences <i>Is it easier to go through a sandy path or a plain one?</i>

SHARE & DISCUSS

Once the experiments are done and the pupils have expressed their reasoning in relation to these concepts, it is time to express and share what they have just discovered and learned. It is important to guide and help them with their answers, in order to enable them to acquire the right competencies for expressing and understanding scientific language. Here, if you consider it appropriate, bearing in mind the abilities of the pupils, you can explain the direction and power of the force with arrows.

THE ENGINEERING PROCESS

It is time to design and build a road (inclined plane) on which a robot will be able to reach the mountain top. Start with a brainstorming session on the meaning of “engineering” and define what steps you have to follow. Keep the groups established and give them a proper support to consolidate the new knowledge at each step.

DESIGN-EXPERIMENT-EVALUATE

It is important to learn how make questions. *If you want to build a proper road, what things do you have to consider?:*

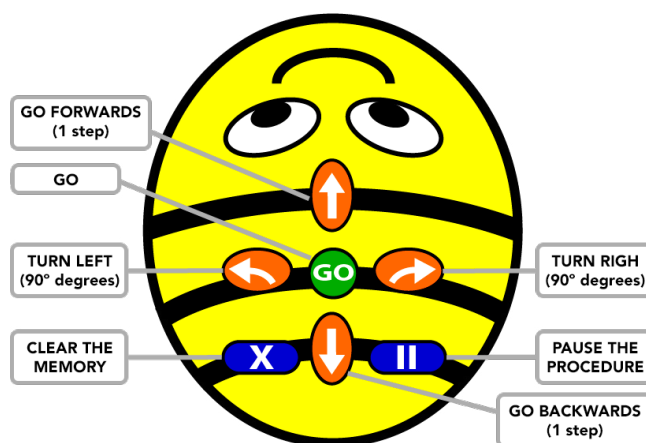
- What is our purpose?
- What do we know about inclined planes?
- Which materials do we need?
- How will we build it?
- How can we program a robot?

Invite the pupils to brainstorm about how to answer those questions. Let them share their opinions and ideas and design what the road will be like. Show them a model of the road, using for example the distance between the floor and a table. Teach them how to program a simple robot to test their design, give them some indications, and let them explore it.

Encourage children to be creative and praise their initiative. Once the prototype is designed, the pupils have to gather the materials they need.

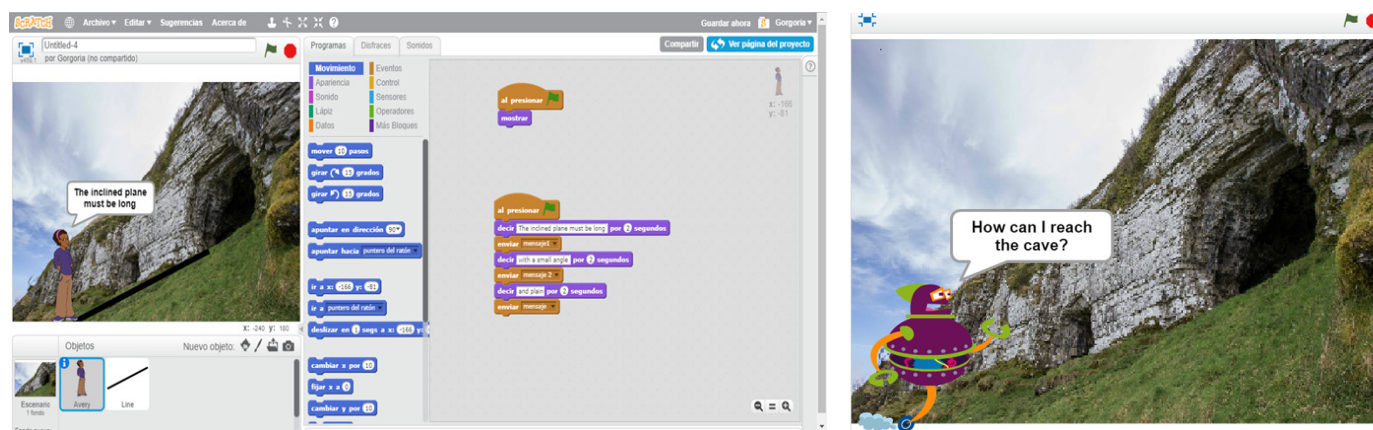
Now, all hands on deck because it is time to cut, glue, paint and... test it out!

Can the robot reach the top? Is the road path safe? Is the road path wide enough? Would you change any feature of the road? With assistance, children have to evaluate their prototype and improve it; everything is capable of being improved!



SHARE & DISCUSS

For older children, pupils can be invited to explain what they have discovered about inclined planes using Scratch. Throughout this program they can consolidate what they have learned and the teacher can evaluate whether they have understood all the concepts properly.



COMPARE-COMPETE

Each proposal will be unique, there are lot of possibilities and the width, the length and the structure can be varied, among other things, so actively encourage the exchange of knowledge and communication in the classroom. Why have they built the road in the way that they have?

Then pupils can measure and compare how much time the robot needs to go up to the cave. It would be also great to analyze how that time is influenced by those variables included in the designs.

Solutions & mixtures



THE SCIENTIFIC METHOD

Mixtures & Solutions.

TECHNOLOGY

Spread your knowledge using Scratch!

THE ENGINEERING PROCESS

Let's make an eco-friendly air freshener.

MATHEMATICS

Measure time and quantity; think, reason, collect data and decide in order to solve a daily problematic situation.

ROBOTICS

Let's program a thermometer and a stop-watch.

CONCISE DESCRIPTION

It seems obvious that the environment is being seriously damaged by our way of life, but fortunately lots of people are aware of this tendency and are committed to come up with ideas to stop this problem. The children are going to make an eco-friendly air freshener, in order to encourage them to take part in this natural issue. This mission requires learning scientific knowledge about mixtures and solutions and reasoning and thinking critically and creatively, as engineers do, to design the prototype. In addition, children have to apply mathematical knowledge on measurement units and attitudes to face problems, technological abilities to share what they have discovered and contribute to greener behavior, and programming skills to program different gadgets.



THE SCIENTIFIC METHOD

In this unit, children are going to become chemists, so they have to know what a chemist is, what they do, and how they behave when they are working in a laboratory. Although work will not be done with chemicals or dangerous substances, the children have to be aware of some rules that apply in the classroom:

- **Never** eat, drink or smell substances.
- **Never** play around during experiments.
- **Always** wash your hands after handling lab materials.
- **Always** read the labels on containers.

PLAY & CREATE

At the beginning of the session, it is important to capture the attention of the children and involve them in activities which arouse their curiosity in a motivated atmosphere where they feel comfortable and confident as active agents in their learning processes. With this purpose in mind, you can start the

class with a problematic situation related to the importance of taking care of the environment and how our daily routines have a huge impact on it. *What can we do to face this problem? Is it possible to take part in it actively? Would it be possible to make eco-friendly products such as a green air freshener so as to contribute to preserve the natural world?* Let's try.

Encourage children to share their opinions and knowledge on this topic and moderate a debate where they can argue, reason and reflect on what they have to know to make an eco-friendly air freshener. *What is an air freshener for? What does it mean to be eco-friendly? What types of air freshener do you know? What knowledge is required to make an air freshener?*



REMEMBER!

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis in keeping with their own experience. So hypotheses are neither right nor wrong, but only offer possible explanations of a certain event.

DESIGN-EXPERIMENT-EVALUATE

After sharing their ideas it is time to define the problem. With the purpose of achieving the objective of making an eco-friendly air freshener, they must acquire knowledge about mixtures and solutions.

Arrange the working groups and distribute different mixtures and solutions, for example:

Mixtures:

- Crayons, rubbers and pencil sharpeners.
- Water and oil.

Homogenous mixtures or solutions:

- A dilute solution of water and sugar.
- A supersaturated solution of water and sugar.

(Variable: amount of solvent. You can start with the variable you consider more appropriate)

Analyze each sample, *what do you observe? What do you think have happened? Can we do anything to make the solutes disappear into the solvents?* After this step, the children have to be able to discriminate between mixtures and solutions and know what substances can be involved, so dedicate enough time to each group using key questions such as the previous ones and use repetition until you notice how the discourse and the actions of the children change. (If you consider it appropriate, distribute worksheets to make this task easier). It would be interesting to encourage the pupils to explain mixtures and solutions from a microscopic point of view.

It does not matter if pupils do not have similar ideas about the topic because this dialogue enables them to develop more complex and better-argued comments. Furthermore, in this stage you can identify what their previous ideas are and thoroughly adapt the learning-teaching process to their needs and abilities.

Now, introduce five different variables: amount of solute, amount of solvent, temperature, speed of shaking, and shape of the solute (icing normal and cube sugar). Explain what an hypothesis is and let them predict what will happen to the samples, if we introduce these variables. *What will happen if we add a huge amount of sugar to one glass and a small amount in another glass, both with the same quantity of water? Do you think that the temperature of water (solvent) affects the dissolving speed of the sugar (solute)?* Ask them to write down their final predictions.

Start with one of the variables and check that the new knowledge has been properly acquired, avoid overwhelming the children with too much information. Let them think about the design of their experiment, what they are going to do and what they need (they will be able to choose between the available materials). During this period you can guide them, asking questions or suggesting some changes or improvements.

Once they have designed the experiment, you can show them how to use scales and a water meter to measure the fixed amount of sugar and water that you have provided each group and ask them to write down the quantities, in order to be able to analyze the data more easily.

Teach pupils how to programme a BBC microbit as a thermometer in order to measure the difference of temperature of the solvents and a stop-watch to measure how much time it is required to dissolve



the solute into the solvent. This can be useful to collect data and to draw conclusions. Here, you have two links to learn how to use a BBC microbit <http://microbit.org/> and a tutorial about how to create a simple temperature gauge: <https://www.youtube.com/watch?v=Hi3Km1PV45M>

It would be a good idea to distribute some worksheets adapted to the needs and abilities of the learners where they can introduce the different variables and the data collected during the process in order to make the task easier.

Now, it is time to organize and analyze the data that has been collected. *How much time is required to dissolve sugar (solute) into hot water? Is the same time required as in a colder one? Are there any differences between a solution with the same quantity of water (solvent) but different quantities of sugar (solute)?*

Children have to draw their conclusions from the data that has been collected, in order to verify or reject their hypothesis. They can likewise formulate new questions.

SHARE & DISCUSS

This is a really important moment because children have to communicate what they have discovered about mixtures and solutions and the way that their previous and spontaneously developed ideas have modified their scientific knowledge can be verified. It is also important that pupils develop a model on the “microscopic” behavior of matter, which could explain their results. With this purpose in mind, pupils can use Scratch, create a poster, a slideshow presentation or a post for the classroom blog.

“

REMEMBER!

The Scientific Method is not a fixed sequence of steps, it is a dynamic process guided by six activities: cooperate, argue, debate, think, record and share.

THE ENGINEERING PROCESS

Now it is time to design and create air fresheners. Start with a brainstorming session about the meaning of “ecological engineering” and define the steps that you have to follow.

DESIGN-EXPERIMENT-EVALUATE

The pupils have already learnt what heterogeneous and homogeneous mixtures are, which substances can be used and what the variables are that affect the solution. Show them the available materials they will be able to use such as dried flowers, slices of lemon, water, mint leaves, fresh lavender and thyme, water, sachets, bicarbonate of soda, bamboo sticks and essential oils, among other possibilities. Show them different options: a spray air freshener, a mixture of dried plants, a reed diffuser or a heterogeneous mixture of citrons and water and ask each group what type of air freshener they are going to make. *Are you going to make a mixture or a solution? What characteristics is it going to have? Is your final product going to be eco-friendly? Why?*

Let children come up with ideas about what their air fresheners will look like, but help them to think and reason about it. Do not forget to encourage them to be creative in their designs and praise their initiative.

Once the prototype is designed, the pupils have to gather the materials chosen and then, all hands on deck because it is time to measure the quantities, cut, mix, dissolve, paint and...test it out!

Is your air freshener eco-friendly? Can you explain why? Is your green product a mixture or a solution? How do you know that? Children have to analyze and evaluate their own product and improve it.



SHARE & DISCUSS

After the whole process, it is time to share the knowledge acquired and Scratch is an appropriate way to do so. The children can create an advertisement to encourage people to make their own product such as theirs and share these ads with other classes even with other schools! Give children some instructions about how to do it and let them discover the application. There are lots of possibilities!

COMPARE-COMPETE

Every single prototype will be unique, there are lot of possibilities and the mixtures, the container, the way to spread the essence, the design and the odors can all vary among other things, so let children draw comparisons between the designs. You can change the air freshener every day and gather data about how much time the odor remains active.

Plants



THE SCIENTIFIC METHOD

What do plants need to live?

TECHNOLOGY

Spread your knowledge by Scratch.

THE ENGINEERING PROCESS

How can we design a proper plant package?

MATHEMATICS

Learn about measurement units.

ROBOTICS

Let's program a BBC microbit to measure the temperature and humidity of the plants.

CONCISE DESCRIPTION

Fortunately, we are still surrounded by a wide range of different plants, like trees, flowers, herbs and shrubs, and it is our responsibility to take care of them. In this unit, the children are encouraged to help environmental conservation in places threatened by deforestation. The children have to create a package to achieve this important objective, so that plants can be transported without any damage during the journey. This mission requires learning scientific concepts about the needs of plants, reasoning about suitable materials and thinking critically and creatively like engineers do, to design the prototype. In addition, the children have to apply mathematical knowledge on measurement units, technological abilities to share what they have discovered and programming skills to program different gadgets.

THE SCIENTIFIC METHOD

PLAY & CREATE

At the beginning of the class, it is important to create a motivational atmosphere. With this purpose in mind, introduce an environmental problem such as the lack of trees in some areas, using a presentation of Scratch. *What can we do to face up to this problem? Is it possible to send plants without damaging them?* Let's try!

Encourage children to share their knowledge about this subject and start a debate where they can argue what they need to know.

After sharing their ideas it is time to define the problem. With the purpose of achieving the objective of sending plants to other places, they must know what plants need to live. Provide one plant to each group and analyze the different parts of the plant and their functions (if you consider it appropriate, distribute worksheets to make this task easier).

Introduce four different variables: sunlight, soil, water and air, explain what an hypothesis is and let children formulate them. Here are some possible examples:

- Plants need water and soil to grow healthy.
- Plants need sunlight to be green.
- Plants can grow without air.

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis keeping their own experience in mind. Hypotheses are neither right nor wrong, but only offer possible explanations.

DESIGN-EXPERIMENT-EVALUATE

Organize four different groups and assign them one variable with which to work. Let them think about the design of their experiment, what they are going to do and what they need (they will be able to choose among the available materials). It is convenient to guide them during this period of group reflection, asking questions or suggesting some changes or improvements.

Ask each group of children to take photos of how plants are changing day after day and use an animation technique called “Stop Motion” to show the process creating the illusion of movement. Here you have a good example: <https://vimeo.com/40950441>

Another interesting option would be to program a BBC microbit as a thermometer and a humidity sensor. These data can be useful when the children have to draw conclusions and afterwards when they have to build a package for the transportation of the plant. Here, you have two links to learn how to use a BBC microbit <http://microbit.org/> and a tutorial on how to create a simple temperature gauge: <https://www.youtube.com/watch?v=Hi3Km1PV45M>

Now, it is time to organize and analyze the data collected during the investigation. *What has happened to the plants after five days? Have they changed? Can you see any differences between them?*

In this process, the pupils can compare their results with other bibliographic resources. This step allows them to verify or to reject their hypothesis. In the same way, they can formulate new questions.

SHARE & DISCUSS

The moment has come for the children to communicate what they have discovered about plants and decide how they wish to do so. For example they could use Scratch, create a poster, a slideshow presentation, or a post for the classroom blog. They could also share their conclusions, modelling the process using the “Stop Motion” technique (creating their own figures in clay).

THE ENGINEERING PROCESS

Now it is time to design and build a package for transporting the plant. Start with brainstorming about the meaning of “engineering” and define the steps that will structure the process to follow.

DESIGN-EXPERIMENT-EVALUATE

Once our children know the needs of the plants, it is time to identify what materials are the best to build a plant package. Show them different types of materials such as plastic bottles, milk cartons, cardboard boxes, plastic wraps, cotton, tape and straws, among other options, and ask which ones they are going to choose and why. The questions should be asked to encourage reflection on the characteristics of the materials and on what they should take into account. *Can this package contain the plant? Will it conserve the plant? Is the selected material sufficiently strong to safeguard the plant?* And finally they should prepare a list of the materials that are chosen.

Let children come up with an idea of how their plant package will be, but help them to think and reason about what they know about plants and the materials they have. Do not forget to encourage them to be creative in their designs, praising and reinforcing their initiative.

“

REMEMBER!

The Scientific Method is not a fixed sequence of steps, it is a dynamic process guided by six activities: cooperate, argue, debate, think, record and share.





Once the prototype is designed, the pupils have to gather the chosen materials and then get down to work because it is time to paint, draw, cut, glue and... test it out!

Does the package meet the requirements to safeguard the plant during a journey? Would you change any aspect of the design? The children have to evaluate their prototype and improve it; everything is capable of being improved!

SHARE & DISCUSS

After the whole process, it is time to share the knowledge acquired and Scratch is an appropriate way of doing so. Give children some instructions on how to handle it and let them discover the application. There are lots of possibilities!

COMPARE-COMPETE

Every single prototype will be unique, there are lot of possibilities so the materials, the color, the size and the weight can all be varied among other things, so let children make comparisons between the designs and help them identify the advantages and disadvantages of those features.

As a complementary activity, and for older children, you can challenge them to create a closed ecosystem. Since both microorganisms and organisms (if there are any) produce CO₂, the plants actually grow very well without air-exchange. So, taking this ecological principle into account, they might try to achieve a closed environment glass-jar with a tight lid. The pupils can observe the behavior of that natural space throughout the year and try to explain how livings beings can survive in that environment. It is a really nice example to explain exchange of matter and energy in a global ecosystem such as the Earth. This link gives an example of how to carry out the experiment: http://www.ecologygateway.com/10683/Kenneth_Snow/The_Science_Classroom/Earth_biosphere/How_to_make_your_own_self_contained_biosphere!

Insulation systems



THE SCIENTIFIC METHOD

What does an insulation system mean?

TECHNOLOGY

Spread your knowledge.

THE ENGINEERING PROCESS

Let's design a thermal insulation system.

MATHEMATICS

At what speed does the heat flow?

ROBOTICS

Let's program a temperature gadget.

CONCISE DESCRIPTION

Heat and temperature are common words often used in our daily routines and they are learnt in a spontaneous and natural way through our social interactions, but frequently our everyday concepts do not agree with scientific ones. In this unit, children are invited to design an insulated system that can keep food under appropriate thermal conditions, to avoid throwing it away and to create awareness of responsible consumption. To do so, the pupils have to learn the scientific difference between heat and temperature, the meaning of an insulated system, which materials are good and bad thermal conductors, and the Scientific Method, as well as any scientist would do. They also have to take into account their findings and think critically and creatively as engineers do, to design the prototype. In addition, the children have to apply mathematical knowledge on measurement units, on technological abilities, to share what they have discovered and programming skills to program different gadgets.



THE SCIENTIFIC METHOD

PLAY & CREATE

At the beginning of the class, it is important to create an atmosphere where kids can feel motivated, comfortable and confident as active agents in their own learning processes. To do so, introduce the topic through a problematic situation and stimulate the interest of the pupils and their initiative to try to solve it.

Throughout the day tons of food is thrown away as rubbish. Food wastage is a really concerning problem and all of us have a responsible role to play in supporting changes in our behavior and attitudes to avoid this situation.

(You can introduce news, videos or data around the locality of the school, in order to offer a broader and closer perspective of the situation).

Discuss this topic and help them to think about their own experiences. Give them the opportunity to express their opinions and help them reason their comments using key questions and paraphrasing their contributions.

- *Do you think this is a real problem? Why?*
- *What are the negative effects of food wastage?*
- *How can we face this problem?*

Introduce and discuss some examples of good practices such as using grocery lists, in order to buy exactly what you need, checking the fridge to make sure it is functioning correctly and make them think about the importance of storing food in places where it keeps itself fresh longer.

Brainstorm ideas with the pupils about how we can maintain the temperature of food constant and write down their comments. This step will help you to identify what their previous ideas are and set up the starting point.

After that, show them some videos and mind maps where concepts such as heat, temperature, insulated systems and good and bad thermal conductors are explained.

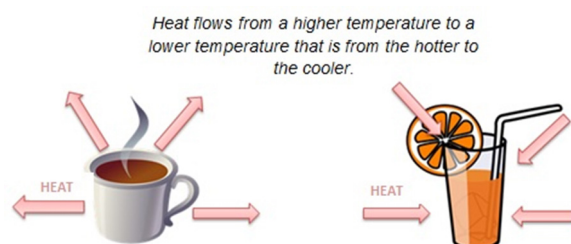
It would be interesting to work with the pupils on how heat is transmitted. The following experiments (that can be done by the teacher or by the pupils) could help the children to understand these complicated concepts more easily:

1. **Radiation:** take three ceramic pots one of them black, another one red and the last one white, fill them with the same water and let the children measure the temperature (you can use the BBC microbit as explained below or just a simple thermometer). Put them in a sunny place or close to a radiator and after some minutes ask the children to measure the temperature again, in order to identify which one is hotter. Children will observe how the water in the black pot is the hottest, because it has absorbed the heat by radiation more than the other ones.
2. **Convection:** pass a transparent container with cold water to each group and introduce a smaller container inside it with hot water and food coloring. After a few seconds add an ice cube made from colored water (different colors would be good, but the children can be left to figure that out) and observe what happens. With this activity, the pupils will be able to see how hot water goes up and cold water goes down.
3. **Alternative convection experiment:** fill two containers with hot water, put a lid on one of them and wait for a few minutes. Observe/feel/measure the temperature of the water or the container surface. The one with the lid will have a higher temperature, since heat is transferred by convection from the water to the air. You could also add a fan blowing above the surface to demonstrate the cooling of the wind. This activity introduces the possibility of creating a thermos-flask at the end, designed to insulate against all three processes.
4. **Conduction:** use three bars made of different materials, wood, iron and aluminum and put some little objects stuck with drops of wax at a fixed distance (you can let children measure the distances between them). After that, apply a source of heat underneath the bars, in order to show how the wax melts in the metal bars because they are good conductors.

Once you have seen how the children have changed their initial arguments, using this new procedure, let them compare, complete or modify their former ideas with this new information and try to guide their discourse, enabling them to develop their arguments in a proper way. Dedicate enough time to each group using key questions and repetition until you notice how the discussions and the actions of the children change.

DESIGN-EXPERIMENT-EVALUATE

Once you notice how the discourse of the pupils and their actions change when taking scientific knowledge into account, it is time to define the problem. With the objective of keeping our drinks or food fresh, they must consider how heat flows and which materials are suitable to minimize that heat transfer.



REMEMBER!

Hypotheses are predictions about a phenomenon based on evidence. Children formulate a hypothesis in keeping with their own experience. So hypotheses are neither right nor wrong, but only offer possible explanations of a certain event.

Tell them what an hypothesis is and introduce the following possible materials:

- A. Cork or foam
- B. Aluminium foil
- C. Newspapers
- D. Plastic wrap

Let them manipulate the materials and predict which ones are good conductors of heat and which ones are not. Help them reason their comments making them think about their experiences and hold them in common. *What happens when you touch a hot saucepan? What do adults use to take the pizza out of the oven?*

Set up different groups and distribute the materials (cork or foam, newspaper, aluminum foil, plastic wrap, carton glasses, scissors, elastic bands and sticky tapes among other possibilities) and let them think through the design of their experiment, what they are going to do, what they have to pay attention to; they have to test out all materials, in order to identify which are good and bad thermal conductors. During this period, guide them, asking questions or suggesting some changes or improvements. There is not only one right solution, so boost their divergent thinking.

Once their insulated systems are built, teach kids how to programme a BBC microbit to become it in a temperature gadget to measure what speed the heat transfers. Here, is a link showing how to use a BBC microbit <http://microbit.org/> and a tutorial about how to create a simple temperature gauge: <https://www.youtube.com/watch?v=Hi3Km1PV45M>

When the BBC microbits are programmed, it is time to test the hypotheses. Pour very cold water into the glasses (even with ice cubes in order to reduce the measurement times) and tell them to check the temperature and to write it down every two minutes over ten or sixteen minutes.

It would be a good idea to introduce some simple worksheets adapted to the needs and abilities of the learners where they can note down their results and afterwards compare them more easily or even introduce the collected data in a computer to draw a graph.

SHARE & DISCUSS

Once the experiments are finished and the children have reasoned about the collected data in their groups, it is time to express and share what they have just discovered and learnt all together.

- *Have you observed any variation in the temperature of the icy water?*
- *Could you explain how heat energy has acted during the experiment?*
- *What is the best material to reduce heat transfer? And the worst?*
- *Would you use the same materials to keep drinks cold and hot? Why?*

It is important to guide and help the children to transmit information, in order to enable them to acquire the right competencies for expressing and understanding scientific language.

THE ENGINEERING PROCESS

Now it is time to design and build an insulated system. Start with a brainstorming session about the meaning of “engineering” and define what steps you have to follow during the process.

DESIGN-EXPERIMENT-EVALUATE

Once the pupils know the difference between heat and temperature, what an insulated systems is and what materials are good and bad thermal



REMEMBER!

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conductors, then that is the moment to define the problem. *What do we want to achieve? Do we want to keep a drink hot or cold? How can we achieve our purpose? What do we need? What does an insulated system entail? What characteristics should be included?*

In this step, introduce a wider range of materials, for instance glasses of different sizes and cork and small pieces of aluminum foil, among other materials. Now, the children have to come up with an idea about what their insulated system will be and draw a prototype. They have to take into account what they have just discovered about heat transmission, but they can also think about new features, such as covering the glass twice or placing the glass into a larger one and covering both containers. Encourage them to be creative in their designs and praise their initiative.

Once the prototype is designed, the pupils have to gather the materials that they have chosen.

Now, it is time to paint, draw, cut, glue and... test it out! Each group will measure and write down the temperature again at different times, as they did in the investigation. Ask them to compare these results with those obtained in the Scientific Method. *Does your new prototype keep the drink hot/cool longer than in the first experiments?* With your assistance, the children have to evaluate their prototypes and improve them; everything is capable of being improved!

SHARE & DISCUSS

After the whole process, it is time to share the knowledge acquired and Scratch is an appropriate way to do so. Give children some instructions about how to do it and let them discover the application. There are lots of possibilities!

COMPARE-COMPETE

Every single prototype will be unique, there are lot of possibilities as the materials, the color, the size and the weight can vary, among other things, so let children make comparisons between the designs and help them try to identify the advantages and disadvantages of those features taking the data that has been collected and the conclusions into consideration.

If you consider it appropriate, start a new project on the connection between saving energy at home and good insulated systems or even about how igloos keep warm inside in spite of being built with icy blocks, or the design of a thermos, in order to let children consolidate and transfer the acquired knowledge to different contexts.

Parachute



THE SCIENTIFIC METHOD

What makes a good parachute?

TECHNOLOGY

Spread your knowledge with Scratch.

THE ENGINEERING PROCESS

How can we design a perfect parachute?

MATHEMATICS

Measure lengths, weight and time.

ROBOTICS

Programme a BBC microbit to measure the time that a parachute needs to reach the ground.

CONCISE DESCRIPTION

Physics concepts such as air resistance, gravity, forces, acceleration and speed can be challenging knowledge to understand for kids, because they require abstraction. However, throughout a STEMRob proposal they will be able to experience them and make them more concrete and easier to comprehend. In this unit, the pupils will be asked to build a parachute for a women's parachuting team. In order to achieve this objective, the pupils have to delve into physical knowledge, to identify the characteristics of a body falling through space, reasoning about the appropriate materials and thinking critically and creatively, as engineers do, to design the prototype. In addition, the children have to apply mathematical knowledge on measurement units, technological abilities to share what they have discovered, and programming skills to program different gadgets.

THE SCIENTIFIC METHOD

PLAY & CREATE

At the beginning of the class, it is important to create an atmosphere of motivation where the children feel comfortable and confident as the active agents of their own learning processes. To do so, introduce the subject through a problematic situation and arouse the children's interest and initiative to find a solution to the following problem:



The 88 member 'Pearls of Russia' women's skydiving team has just successfully pulled off a white, blue and red flower formation jump in the skies over Kolomna near Moscow, setting a world record for women's parachuting. Their first two attempts were not successful, but the third time worked perfectly. The previous world record had been set by a German female team, which consisted of 84 women.

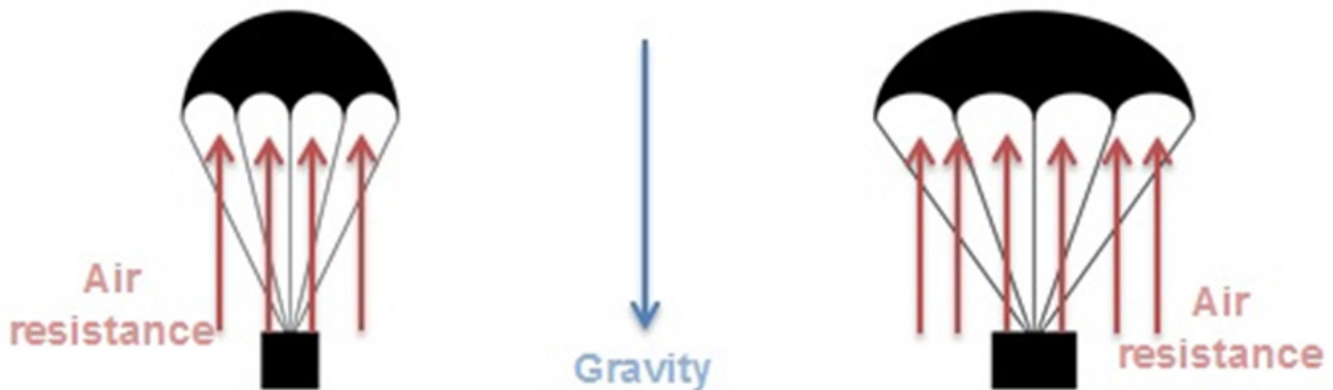
<https://www.youtube.com/watch?v=fMswcVNyXIs>

Would you like to help this team to design a new parachute for their next competition?

Brainstorm ideas with the pupils about what a parachute is, what it is for and how it works. Show them some videos where concepts such as drag and gravity will be explained and invite them to extract and discuss the relevant information. Try to guide their discussion, helping them develop their arguments in a proper way.

Set up working groups and hand out two parachutes with different features to each group and let them play, explore and discover how the parachute drops are affected by the peculiar features of each parachute. Dedicate enough time to each group using key questions and use repetition until you notice how children's discussions and actions change. Do not forget to encourage them to share with their peers what they are observing. Remember, language is an indispensable element to acquire significant knowledge.

It would be also a good idea to introduce some simple worksheets adapted to the needs and abilities of the learners where they can see how forces act on a parachute when it falls. They can also be encouraged to think about situations when they have felt air resistance perhaps when riding their bikes or playing on a swing.



DESIGN-EXPERIMENT-EVALUATE

Once the pupils have varied their way of thinking, the time comes to define the problem. Define a specific height from which the 'jump' starts. With the purpose of achieving the objective of building a perfect parachute, they must know what characteristics are involved.

Tell them what an hypothesis is and introduce the following variables which influence both forces, drag and gravity and consequently the speed and acceleration that the parachute acquires during its fall:

- A. The size of the parachute canopy.
- B. The length of the suspension lines of the parachute.
- C. The weight of the parachute.
- D. The material of the canopy.

Give one variable to each group and let them predict what will happen if they modify it. When they have defined the hypothesis they should tell their partners about it and give some reasons.

Organize four different areas where children can verify their hypothesis:

- Area 1 - Parachutes with canopies of different sizes.
- Area 2 - Parachutes with different suspension line length.
- Area 3 - Parachutes with different weight.
- Area 4 - Parachutes with canopies of different materials.

Let them discuss the design of their experiment, what are they going to do, what they need, and what they have to take into account. During this period, guide them by asking questions or suggesting changes or improvements. There is no one correct solution, so stimulate their lateral thinking!

Encourage the pupils to test their parachutes by letting them drop from a certain height (higher drops will give better results). Teach them how to program a BBC microbit to become a stop-watch to gather better data and measure how much time the parachute takes to drop to the ground. These data can



REMEMBER!

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be used to make comparisons afterwards with the other groups. Here is link to a site on how to use a BBC microbit <http://microbit.org>. Most of the codes can be programmed by blocks like Scratch, so you can adapt the difficulty to the programming skills of your pupils.

Before finishing this part of the investigative process, it would be a great idea to use a slow-motion technique to observe the trajectories of the parachutes as they drop. If the parachute is good enough, the terminal velocity will be constant, with no acceleration. The children can observe this phenomenon attaching a BBC microbit to the parachute. When the speed does not vary the LEDs will not light up but when there is acceleration they do light up. Here is a link where you can obtain the code <https://bit.ly/2lw3ZPV> that is needed. The group can also record a 'jump' without a parachute for comparison.

SHARE & DISCUSS

Once the experiments are done and children have reasoned about these concepts, it is time to express and share what they have just discovered and learnt. Encourage them to prepare a digital presentation where they can explain the properties of their parachute, what they have done to get data, what they have observed, and what conclusions they have drawn.

It is important to guide them, helping them to transmit information, so that they can acquire the right competencies for expressing scientific language and for understanding it.

THE ENGINEERING PROCESS

Now it is time to design and build a parachute. Start with a brainstorming session on what an "aerospace engineer" does and define what steps you have to follow. Remember that it is a dynamic process so you can go back and forth through the steps.

DESIGN-CREATE-EVALUATE

The children have already learnt some of the characteristics that affect the fall of a parachute. Now, they have to define the problem, *what do we want to get? How can we achieve our purpose? What do we need? What defines a good parachute? What characteristics must be included?*

In this step, children have to come up with an idea about on what how their design of a parachute will belook like. They have to take into account what they have just discovered about in relation to the characteristics of a parachute, but also think about new features. For instance, the shape of the canopy – *will it make any difference?* Encourage them to be creative in their designs and praise their initiative.

Once the prototype is designed, the pupils have to gather the materials that they have chosen.

Now, it is time to paint, draw, cut, glue and... test it out! Let them check the designs of their parachutes several times. Ask them to write down how much time it needs to drop to the ground and to compare these results with those obtained in the Scientific Method. *Does your new prototype need more or less time than the other parachutes to drop to the ground? How do you explain the differences?* With your assistance, children have to evaluate their prototype and improve it; everything is capable of being improved!

SHARE & DISCUSS

After the whole process, it is time to share the knowledge acquired and Scratch is an appropriate way to do so. Give children some instructions about how to do it and let them discover the application. There are lots of possibilities!

COMPARE-COMPETE

Organize a space where every group can enter into dialogue together and suggest that they compare their prototypes with the intention of identifying, only by observing their features, which one seems to be the best; in other words, which takes longest to drop to the ground. Then, verify their predictions based on their knowledge, for which purpose they can use the previously programmed stop-watch.

04

OPEN EDUCATIONAL RESOURCES

STEAM RESOURCES (WEBSITES, VIDEOS)

La main à la pâte

A wide variety of resources and activities, using inquiry methodology, for different educational stages, and scientific and pedagogical documentation.

<http://www.fondation-lamap.org/en/international>

Scientix

Scientix is a project funded by the European Commission and coordinated by European Schoolnet (EUN). It includes a great variety of resources and activities that can be filtered by age (min. and max.), topics, resource types.... The project also offers the opportunity to join a community of STEM teachers, following courses and webinars, and participating in conferences.

www.scientix.eu/home

CREST awards

CREST awards were created by the British Science Association for young people from 5-to-19 years old, accrediting project work in STEM. Activities are classified by topics and difficulty levels and delivered by educators using an inquiry-based approach and connected with everyday experiences. It also includes materials for students with Special Educational Needs (SEN).

www.crestawards.org/run-crest-awards/crest-star

City Technology

Resources aimed at different grades integrating engineering, science, math, literacy and art, where the children develop different projects with materials from their everyday life.

www.citytechnology.org

Engineering is Elementary

Complete curricula for different stages (Kindergarten and primary school) with activities to be carried out inside school and activities to be developed at workshops outside school. The curricula are composed of different units, which refer to a variety of themes (life sciences, geology, electrical engineering, aeronautical engineering).

www.eie.org

EDUTOPIA

Different resources for teachers and parents, on topics such as emotional learning, technological integration, project-based learning..., as well as videos on the same topics.

www.edutopia.org

Exploratorium

Professional development program addressing the theory and practice of inquiry-based science education, with videos for different experiments done with children, commented step by step and a variety of activities to teach different aspects of STEM and other topics, as well as apps, blogs and a collection of references and literature.

www.exploratorium.edu/education

Teach Engineering

Educator Guide about tele-robotics and other new media, technology-based arts. STEM curriculum for K-12

<https://www.teachengineering.org>

Science sparks

YouTube channel with STEM practices for children. They have also a website www.science-sparks.com. The channel includes videos of different activities related with science and inquiry-based learning, which also includes some robotics.

www.youtube.com/channel/UCoy2L2ZIm8bglFwaQlhkIAw

Backyard Science

Australian educational television show for children in which children experiment with everyday items in order to make something fun and practical and offer scientific knowledge in the world of a child.

https://www.youtube.com/playlist?list=PLfZdHBvCxqweCJ68krrkQH04z79c_RJq9

Kodo Kids

Channel is focused on designing and manufacturing open-ended tools and toys to reaffirm childhood and empower children. The channel offers STEM activities and other videos.

www.youtube.com/user/KodoKids

David Lee EdTech

Videos of different activities aimed at primary school children: forces and interactions, pushes and pulls, using inquiry-based and problem-solving approaches.

www.youtube.com/channel/UCPOvRMktU0x4qRTIjD6aE4g

ROBOTICS, PROGRAMMING AND COMPUTING (WEBSITES, VIDEOS, RESEARCHES)

Kojo Learning Environment

Kojo is an open source App. It is a Learning Environment - with many different features in the areas of: Computer Programming and Computational thinking, Maths and Science, Inductive, Deductive, Systematic, and Analytical thinking, Art, Music, and Creative thinking, Problem-Solving strategies, Electronics and Robotics, Computer and Internet literature.

www.kogics.net/start

LightBot

Solve puzzles using programming. LightBot is a puzzle game based on coding; it secretly teaches you programming logic as you play.

www.lightbot.com

BBC Schools primary computing

Computing around the web. Different computing resources for primary and secondary students.

www.bbc.co.uk/schools/0/computing/28972462

Your first robot

"Your First Robot" gives you the complete step-by-step instructions for 15 different easy robotics projects.

www.instructables.com/id/Your-First-Robot

Hour of Code

Free workshops, lessons, and videos to help educators and students with the basics of coding.

www.code.org

Scratch: Imagine, Program, Share

Gateway for accessing the Scratch resources (a specific coding system initially planned for Young children and educational uses).

www.scratch.mit.edu

Early Childhood Robotics Network

A site started by the Dev. Tech Research Group at Tufts University to connect and support educators using early childhood robotics.

www.tkroboticsnetwork.ning.com

DevTech Research Group

The Developmental Technologies Research Group at the Tufts University, aims to understand how new technologies that engage in coding, robotics and making, can play a positive role in children's development and learning.

www.ase.tufts.edu/DevTech/index.html

Sphero

Helps teachers to generate ideas on the use of Sphero Robots in their classrooms. Primarily for STEM/science teachers, Sphero can be used in any curriculum.

www.youtube.com/watch?v=oTtSOC8gpQo

Article on Female role models creates interest in programming

Female role models stimulate interest in programming.

www.pedagog.stockholm.se/teknik/kvinnliga-forebilder-skapar-intresse-for-programmering-/

TED talks

Ted talks on Robots. As machines grow ever more intelligent, they are not only emerging as powerful tools, but also as close companions. These TED Talks offer both whizzy demos and serious ideas on our evolving relationship with robots.

www.ted.com/topics/robots

SPARKed - Spark in Education (Educator's Guide)

Guide written by Ken Goldberg merging robotics and the social behavior of internet communities in a series of whimsical artistic "experiments".

www.oercommons.org/courses/technophiles-ken-goldberg/view

Khan academy – Intro to computing

Videos made by the Khan academy for disseminating essential contents and basics on computing and coding.

www.youtube.com/channel/UCye0TMXdb_zdfvVgXAOXtkA